# NAVAL POSTGRADUATE SCHOOL Monterey, California



# **THESIS**

EVALUATION OF THE NASA-AMES PANEL METHOD (PMARC) FOR AERODYNAMIC MISSILE DESIGN

by

Mark A. Lambert

September, 1995

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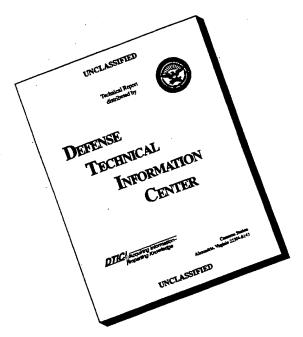
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# EVALUATION OF THE NASA-AMES PANEL METHOD (PMARC) FOR AERODYNAMIC MISSILE DESIGN

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# **ABSTRACT**

The NASA Ames Research Center developed panel code (PMARC) is investigated to explore its suitability for aerodynamic missile design purposes. To this end, PMARC is first assessed by applying it to several problems for which other solutions and experimental data are available, i.e., steady flow past a wing-body configuration, delta wings, biplane wings, wings in ground effect, and unsteady flow of pitching and impulsively started wings. Good agreement is found in all cases. PMARC is then applied to two missile configurations. Again, encouraging agreement with available experimental data is found provided the wake shedding from the missile body is modeled properly.

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#### I. INTRODUCTION

Typical air-to-air missile aerodynamic design work is done primarily using semiempirical chart or computer tools. These tools are limited to previously investigated missile configurations and flight regimes. Another method to be used for initial design tasks may be the use of a relatively "inexpensive" code like the NASA-developed Panel Method-Ames Research Center (PMARC) software. This code allows for any arbitrary configuration to be modeled within the limitations of inviscid, incompressible aerodynamics.

The purpose of this work is to determine if the PMARC computer code provides a viable tool for initial design tasks of tactical missile airframes. All of this work is conducted on the Naval Postgraduate School's (NPS) computer systems. The majority of the work is completed on the Department of Aeronautics and Astronautics Silicon Graphics Incorporated (SGI) workstations while much of the unsteady computations and other large jobs are run on the NPS Computer Center's Y-MP EL98 Cray computer. The analysis of oscillating wings requires a large amount of memory and processor time. This part of the study is done exclusively on the Cray computer.

The scope of this analysis is to understand the design capabilities of the PMARC code in terms of initial missile aerodynamic design tasks. The approach is to validate PMARC against existing data. Steady as well as unsteady flows are modeled by PMARC. Comparisons are made for each type of flow. The ability to provide design data is examined to validate the usefulness of PMARC as a missile design tool.

Initial work is done to verify previous results using PMARC, and comparisons are made to existing experimental and theoretical data. The primary focus of the remaining work is to evaluate PMARC for the analysis of missile configurations. To this end, two missile configurations are investigated.

### II. OVERVIEW OF PMARC CODE

The PMARC code is used to computationally predict inviscid, incompressible flow fields around arbitrarily shaped three-dimensional configurations. All solutions presented in this study are produced using version 12.21 of the PMARC code. The principal limitation of the PMARC code is that it is based on potential flow modeled by the Laplace equation [Ref. 1].

$$\nabla^2 \Phi = 0 \tag{2.1}$$

The lack of viscous modeling inhibits the computation of drag due to viscosity, but the induced drag due to lift  $(C_{Di})$  may be calculated. As an example, for a symmetric wing at zero angle-of-attack (AOA) in uniform flow, PMARC calculates zero drag force which reproduces the classical d'Alembert's paradox.

PMARC also provides some capability to model internal three-dimensional and jet flows [Ref. 2]. The modeling of a complex three-dimensional body in PMARC requires extensive experience and understanding of the PMARC construction process. An excellent supplementary introduction on the general use of PMARC is shown in a NPS prepared manual [Ref. 4]. Reference [4] is limited primarily to the discussion of using PMARC to analyze wing shapes and does not provide specific information on wing-body configurations.

PMARC is written in FORTRAN with an open architecture to allow easy user modification to the code. Also, provided the user has access to the source code, PMARC can be resized (i.e., the maximum number of panels can be changed) in a matter of minutes to optimize the code for the model size being run. This type of utility is discussed in more detail later.

The body representation of the flow potential is modeled by constant strength source and doublet distributions over each panel. The use of constant source distributions indicates that PMARC is a low-order method. The code uses an internal Dirichlet boundary condition at each discretized point on the surface in order to solve the velocity potential at that point. Therefore, the sources are explicitly determined based on the external normal velocities which is zero for a configuration with no jet flow (i.e., no flow through the surface) and the known onset velocity vector [Ref. 1]. The doublet strengths are determined using an integral equation which prescribes the condition on the inner potential. The inner potential defines the velocity field on

and around the body. The shed vortex sheets are generated by wake doublet panels, and the vortex strength is calculated by applying the Kutta condition at the trailing edge for lifting wings [Refs. 2, 5]. For lifting bodies, such as missiles, the doublet strength of the wake panels being shed from along the body length is calculated by differencing the doublet strength of the neighboring panels whose common edges define the wake separation line [Refs. 1, 2].

PMARC employs a time-stepping wake model routine that allows the user to specify a prescribed motion for the paneled configuration. This provides analysis of modeled bodies executing maneuvers or oscillating motions. The time-stepping routines permit the solution of either steady or unsteady flows to be solved as well as investigating indicial aerodynamics. The wakes from the modeled geometry are developed over a series of time steps and show the development of the flow and wake trajectory [Ref. 1].

# A. GENERAL PMARC USAGE

The use of the PMARC code consists of generating an input file necessarily named DATA5 which contains the information defining the geometry of the model as well as the flow conditions and any boundary conditions imposed. This process in PMARC is similar, albeit much simpler, to the meshing process needed in a full Computational Fluid Dynamics (CFD) analysis.

A DATA5 input file for a wing-body configuration is shown in the PMARC manual [Ref. 1]. Sample DATA5 input files are included in the appendices for a similar wing-body configuration [Ref. 23] and also for a more complicated canard-tail-body missile model [Ref. 21, 22]. Additional input files for basic wing models are shown in Ref. [4] and in the appendices. For the beginning PMARC user understanding the analysis of a basic wing model is the best place to start.

# 1. Running PMARC with an Existing Executable

Assuming a PMARC executable file (e.g., pmarc12) has already been placed in a user executable directory (e.g., /usr/local/bin), the only other necessary item needed to produce a set of PMARC output is the input file named DATA5. Several sample input files can be copied into a user directory from the /usr/local/PMARC\_Models directory. Typically, a user subdirectory (e.g., /d4/smith/pmarc) is created and used to store the data files. The following is an example of

a command which can be issued at the UNIX prompt to copy a file into the current user directory:

## cp /usr/local/PMARC\_Models/planform1 DATA5

This copies a PMARC input file named "planform1" into the current directory and changes its name to DATA5. This file contains the information to model a NACA 4-digit wing. There are other input files located in this PMARC model directory that can be copied into the user directory. To execute PMARC, the following command is entered at the UNIX prompt:

#### pmarc12

At the end of a successful run, two other files (DATA6 and DATA22) are generated in this directory. These are the only two output files left at the end of the run as the several other "fort" files appearing during PMARC execution are temporary files and they are deleted automatically.

The DATA6 output file contains all the information generated by PMARC in ASCII form including the aerodynamic coefficients and the geometric data. The DATA22 output file contains the information used in the post-processor visualization program. This code is discussed later.

Two corrections are noted from material presented in the Subsonic Load Analysis Manual [Ref. 4]. First, it states that only the DATA5 input file can exist in the current directory when executing PMARC. Actually, any number of files can exist in the directory with DATA5 as long as they are not named the same as any of the PMARC output files (i.e., DATA6, DATA7, DATA22, fort.16, fort.18, fort.19, fort.20, and fort.21). Second, the wing model for the NACA 6-digit input file included in the manual shows data points defining the airfoil section starting at the wing leading edge. PMARC handles wing analysis best when the wing is constructed from the trailing edge and wraps continuously around the underside to the leading edge and back to the trailing edge. This allows the slope discontinuity in the wing patch to occur at the trailing edge where the wake is forced to separate. Otherwise, erroneous results may occur when calculating the aerodynamic coefficients for the wing.

# 2. Creating a PMARC Executable

A situation might exist where only the PMARC source code is available, and it has not been compiled. Similarly, a new executable might be needed if the existing PMARC executable is compiled with certain arrays (e.g., the number of allowable surface or wake panels) set too low

for the current model. For example, if the PMARC executable available on the system is compiled with a maximum allowable number of surface panels set at 2000, and the user model requires 5000 panels then a new executable should be compiled with a larger number of allowable panels indicated.

Three files are needed for compiling the PMARC code: the PMARC source code (i.e., pmarc12.f), PARAM.DAT, and COMMON.F. The COMMON.F file deals with the FORTRAN common blocks inside the PMARC source code. It is unlikely a user would need to modify this file unless modifications are made to the source code itself. A typical item to change in PARAM.DAT is the NSPDIM parameter which sets the limit on the number of surface panels allowed on the current model. It is important to note that the number of specified surface panels needs to be only as large as necessary to run the current model. If this parameter is set unnecessarily large, it drives up the memory requirements for running PMARC which can slow down the execution of the code especially if operating on the Cray computer. Reference [1] discusses the memory requirements based on the user specified size of the input arrays.

To update a PMARC executable to reflect the current values of the parameters in PARAM.DAT, the source code must be recompiled. Changing the values in PARAM.DAT without recompiling the source code will have no effect on the current executable being used.

If a user is operating with his own copy of the source code, it is recommended that the PMARC executable be placed in a "bin-type" subdirectory which is searched from all locations of the user's account. This allows the user to execute PMARC from any subdirectory. The path must be set in the user's .login file to alert the system that it should search this bin directory for executables. The path should be set to the user's particular disk and user name. A line like the following should be placed in the .login file:

#### set path = (/d4/smith/bin \$path)

While inside the bin subdirectory that contains the pmarc12.f, PARAM.DAT, and COMMON.F files, the following command is issued on a SGI workstation to create a PMARC executable called "pmarc12\_2":

# f77 -o pmarc12\_2 pmarc12.f

A different name should be assigned to the new executable other than the one residing on the system to avoid confusion (e.g., pmarc12\_2 instead of pmarc12). This different name can be any

chosen by the user to help identify the PARAM.DAT parameters set for that given executable. If compiling on the Cray computer the same process is followed except the command is:

#### cf77 -o pmarc12\_2 pmarc12.f

There are also different options for compiling on the Cray to take advantage of vectorized and parallel processing capabilities. The above Cray command shows a process that will generate a functional executable without any optimization.

After the above steps are taken, typing the command pmarc12\_2 at the UNIX prompt in a subdirectory containing a valid DATA5 input file should properly execute the PMARC code and generate the DATA6 and DATA22 output files.

### B. GEOMETRY MODELING IN PMARC

As in any mesh generation for CFD or Finite Element Analysis (FEA) knowledge of the tools available and their limitations is based on experience and training. The true "art" of such analysis is being able to determine what makes a viable grid and what does not. The accuracy from any type of computational analysis is limited by the assumptions and capability of the computer code being used. The best way to start modeling in PMARC is to modify an existing file that is similar to the model of current interest. Several sample input files currently exist on the Department of Aeronautics and Astronautics SGI workstation network.

When dealing with a NACA 4-digit airfoil, like a NACA 2412 for example, PMARC offers an automatic airfoil generation option. This process is well outlined in Ref. [4]. The user has options in specifying the number of spanwise and chordwise panels as well as the desired aspect ratio. For more complicated cross-sections like a NACA 6-digit airfoil, a set of actual discretized panel points must be inputted to the DATA5 file as shown for the NACA 65-412 airfoil in Ref. [4].

The generation of a wing-body geometry is a more complicated process. Now the wing must be modeled as before plus the body must be coupled with the wing. Reference [1] and several appendices show sample DATA5 input files for several wing-body configurations. What must be understood is that the wing and body panel points must be aligned so that there are no holes in the interface between the surfaces. This requires an effort in defining the geometry precisely and accounting for each and every panel corner point location. As seen in any of the wing-body input files the panel spacing on the body must correspond to the chordwise panel

spacing on the wing. Unfortunately, since each panel intersection point along the fuselage must be manually placed to match the wing points, changing the number of chordwise wing panels at a later time becomes very arduous. Hence, it is beneficial to initially know the best panel configuration, but obviously this is not always possible.

# C. GRAPHICS VISUALIZATION

# 1. The General Visualization System (GVS)

Another code to be used in addition to PMARC is the NASA GVS software [Ref. 3]. This is a post-processor software which takes the graphical DATA22 output file from PMARC and provides visualization of the geometry and flow parameters. The documentation for the GVS Version 3.1.00 used here is very limited [Ref. 3]. Fortunately, the GVS software is mouse driven, fairly intuitive and easy to use for most general cases. A supplementary explanation of the GVS software is made in Ref. [4].

The GVS software is useful when initially constructing a geometric model. PMARC has the option of running the model for the geometry only. This allows the user to quickly visualize the geometry and check it for errors. This is beneficial because PMARC is unforgiving when syntax errors exist or any required terms are omitted in the DATA5 input file. PMARC does not contain any internal diagnostic type programming. At best, when an input error is made in DATA5, the user can expect a cryptic FORTRAN error message which does not provide much help.

# 2. GVS Operation

This section provides a general overview of the GVS setup and operation and is included for the sake of completeness. The basic process to set up an user account for GVS use is as follows. First a user subdirectory called GVSDIR is created. Second, the directories and files from /usr/local/GVSDIR\_INSTALL are copied into the GVSDIR subdirectory. When this is completed the GVSDIR directory should have two subdirectories: /TMP, and /LOCAL. Now the GVS code can be run by making sure the current directory is GVSDIR and entering the command gvs at the UNIX prompt. Several windows will appear after a few seconds.

# a. Loading a PMARC Output File

To load a DATA22 file the proceeding process must be adhered to. One GVS requirement is that the DATA22 file must be changed to any name not exceeding eight characters with the extension of .fmt (e.g., wingout.fmt). In the File-Access box click the mouse on the Mod-File-List button. Click on the Null button and it changes to PMIPS. Click on the File-Name button, and type in the path to the PMARC output file in the highlighted space (e.g., /sirius/d1/smith/pmarc/wingout.fmt). Now click on the Add-Name button, and then click on the Close button. The path and file just entered should appear in the File-Access box. Click on the new File-Path button to highlight it, and then click on the Acquire button. GVS should indicate that it has started to load the selected file. The PMARC model geometry should appear in the Graphics Window after GVS has finished loading the selected file. This process to read a graphics input file into GVS is outlined in more detail in Ref. [4].

#### 3. Flow Phenomena Animation

A useful option while visualizing wake time steps is in the Keyframe-Control box in GVS. Inside the Keyframe-Control box is the PMARC-Enabled box. The use of this option can be illustrated in the following example. If the Cp distribution on an oscillating wing is selected, and the shed wakes are animated, then what is seen on the wing is the color contour Cp distribution for the first time step. By default, this Cp contour does not change with each time step. When the PMARC-Enabled box is clicked on, it changes to PMARC-Phenomena-Always-On. This option allows the Cp distribution to be updated with each time step along with each shed wake. This shows the user how the pressure is changing over the object at each subsequent time step. By activating this option, the animation process can be slowed significantly since the computer is updating the Cp color contour for each time step. For steady state problems, updating the Cp color contour is not as much an issue, but the option can still be used to visualize the developing flow field. This process can be used to update any of the flow phenomena calculated in PMARC (e.g., velocity magnitude, doublet strength, Mach number, etc.).

# 4. Plotting from GVS

Another option which is mainly used when generating hardcopy outputs from GVS is changing the background color of the geometry window. The default background of the graphics window is black, and the object is white. This provides a rather poor color combination for producing plots. By selecting the Color-Set box an option for selecting background color is provided. Selecting the background color to white and the object lines to color will allow a better plot to be created.

The built-in output generation capability of GVS is found to be insufficient. The SGI "snapshot" function produces a better plot. The snapshot function saves a user selected window area as a RGB file. Options to convert this RGB file into a plottable postscript file are either to use the SGI "tops" function or to read the RGB file into the "xview" program (e.g., xv filename.rgb), and then save it as a postscript file (e.g., filename.ps). Now this file can be sent to a postscript printer.

#### III. DATA EXTRACTION

The DATA6 output file from PMARC can contain a large amount of data generated during program execution. There are different user-selected options in the DATA5 input file to control how much data is written to the DATA6 output file depending on the needs of the user. This section is a brief overview of how a user might use the UNIX environment to extract certain pieces of data automatically from the PMARC output file. Two sample UNIX script codes are included for reference.

Often only one or two particular coefficients are of interest for a given run. For a steady state solution, it is a fairly easy task to edit DATA6 and extract the data of interest. It is, however, inefficient to edit the DATA6 file to extract the data for each time step for an unsteady case. As an example for the oscillating wing cases that are discussed later, there could be a few hundred time steps and the C<sub>1</sub> value at, say the mid-chord, is of primary interest. Obviously, manually extracting these values at each time step from DATA6 requires a large amount of time. The following information presents options on extracting such data in a semi-autonomous method.

Shown here is the use of the UNIX Awk language to extract the desired data for a few general cases. The use of the Awk and Grep commands directs the computer to filter through a file for a particular phrase or character grouping and then extract the selected field or number. This proves to be a useful tool in the data manipulation of PMARC output data. A "script code" in UNIX is simply a list of input commands placed in a file and then executed. These commands can be individually executed by the user at the UNIX prompt, but by placing them in an executable script file an efficient method to do repeated data extraction is created. The extracted data is piped into a file in ASCII format which is read into any plotting routine or a program like MATLAB and then shown graphically.

The script code in Figure 2.1 is used to extract the  $C_1$  and  $C_m$  values at the mid-chord of an oscillating wing at every time step for a given run. The script code in Figure 2.2 is used to extract the total coefficients for the body-fixed reference frame for a missile model at each time step.

```
#!/bin/tcsh
echo
echo Process to extract cl and cm from DATA6 PMARC output file
echo
echo \<Please stand by\: Processing DATA6 information\>
grep WIND DATA6 > out1
awk 'prev=="AXES" {print} {prev=$2}' out1 > out2
awk '{print $2,$5}' out2 > clcm
      out1 out2
rm
echo
echo The output file name is \"clcm\"
echo
echo Then this can be read into Matlab or some other graphics routine
echo Each line is a time step \(determined from PMARC input\) starting
echo at time step \#1. To get time step \#0 you\'ll have to manually
echo load that from DATA6 into clem since the awk command skips
echo over that particular line of data
```

Figure 2.1 Sample Data Extraction File.

```
#!/bin/sh
# AWK Script to extract values from the PMARC output DATA6 file.
# Finds "BODY AXES" and skips 59 lines then picks first field ($1)
# which is the total CN value and second field ($2) which is CA
# and fourth field ($4) which is the C_m value
echo
echo Reads in DATA6 file and
echo CN, CA, C_m data is put in file aimout
awk '
     /BODY AXES/ {
              NL = 59
              for(i=0;i<NL;++i)
                                     # Gets 59 line after BODY AXES term
              getline
                                    # Gets fields
              print $1, $2, $4
      ' DATA6 > aimout
```

Figure 2.2 Sample Data Extraction File.

For a steady case problem, such as is examined for the missile models, the time step information is not as important. What this allows the user to easily see is how quickly the code converges to the steady state solution by examining the change in the coefficient values over the range of time steps specified. This might indicate that more time steps are needed to properly reach some convergence criteria.

For proper use of the codes, these script codes must be made executable in the UNIX environment. This is accomplished by using the following command at the UNIX prompt:

#### chmod +x scriptname

Where the "scriptname" in this case is whatever user-defined filename is given to the script file. These codes can be modified to fit many different data extraction needs. By changing the term to be searched for, the number of skipped lines, and the character fields to be extracted many different possibilities on data manipulation are evident. For further information on using the Awk and Grep commands, see Refs. [6, 7].

#### IV. VERIFICATION OF THE PMARC CODE

It is felt that to properly understand the important aspects of the PMARC code and to establish confidence in the numerical results that a series of comparisons between the PMARC results and published results is needed. Therefore, comparisons are made of steady state flows, oscillating wing cases, indicial aerodynamic responses, and wake interference results.

### A. STEADY STATE COMPARISONS

# 1. Wing-Body Configuration

In the PMARC instruction manual [Ref. 1] a case for a slender body with wings is presented for a comparison of pressure coefficient (Cp) values over the upper and lower surfaces [Ref. 8]. Shown in Figure 3.1 is the wing-body geometry, and in Figure 3.2 is the Cp distribution from experimental data and from the PMARC output. Within the resolution of the presented data, the Cp comparison appears fairly close. A lift coefficient (C<sub>L</sub>) comparison is made between a PMARC model and published results from Rom [Ref. 9]. The configuration is similar to that of Figure 3.1, but it has a blunt tail as seen in Figure 3.3. The comparison shown in Figure 3.4 indicates a reasonable agreement between Rom's data and the PMARC data.

# 2. Delta Wings

A comparison is made between PMARC and published experimental  $C_L$  results of delta wings with two different aspect ratios from Bertin and Smith [Ref. 10]. The comparisons in Figure 3.5 show good agreement in the low AOA regions and then an increasing deviation as the AOA exceeds  $10^{\circ}$  to  $15^{\circ}$ . This type of behavior is expected since the PMARC code is linear in AOA.

The delta wing with aspect ratio of 0.83 demonstrates an increased experimental C<sub>L</sub> above the linear PMARC result at higher AOA due to the generation of vortex lift caused by the wing configuration. By using a simple trailing edge shed wake model in the PMARC analysis, no attempt to model the vortex lift is made. The additional lift from the vortex formation is seen to diminish as the AOA approaches 40° due to the vortices bursting soon after formation. A delta wing with an aspect ratio of 0.83 has a long chord to span ratio which enhances the vortex lift effects.

The delta wing with the aspect ratio of 3.97 shows a linear relationship of the experimental data until lift is reduced at around an AOA of  $20^{\circ}$ . This delta wing has a longer span to chord ratio which reduces the effect of any additional vortex lift. The developing vortices simply cannot affect a wing of this shape as much as in the case of the 0.83 aspect ratio delta wing. Therefore, for the aspect ratio 3.97 delta wing no significant additional vortex lift is generated. However, the lift curve slope,  $dC_L/d\alpha$ , becomes progressively smaller as the aspect ratio decreases [Ref. 10]. This is seen in the comparisons made in Figure 3.5.

# 3. Biplane Wings

An analysis is done by Milne-Thomson [Ref. 11] on the effects of two-dimensional airfoils flying in close proximity to one another in a biplane configuration. This analysis indicates the top airfoil has higher lift than the lower. This result is confirmed by PMARC for an aspect ratio 20 wing at an AOA of 10° as shown in Figure 3.6. Although not shown here, Milne-Thomson also shows that the lower airfoil would have less drag than the top airfoil. These effects are seen to decrease as the distance between the airfoils increased. As shown in Figure 3.6 the pair of two-dimensional wings provides a higher  $C_L$  than the aspect ratio 20 wings.

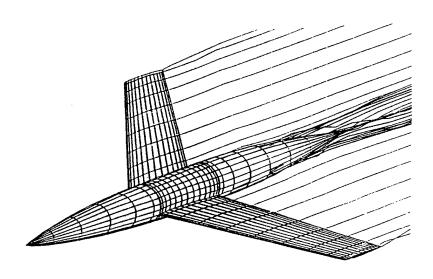


Figure 3.1 PMARC Wing-Body Panel Geometry, From Ref. [1].

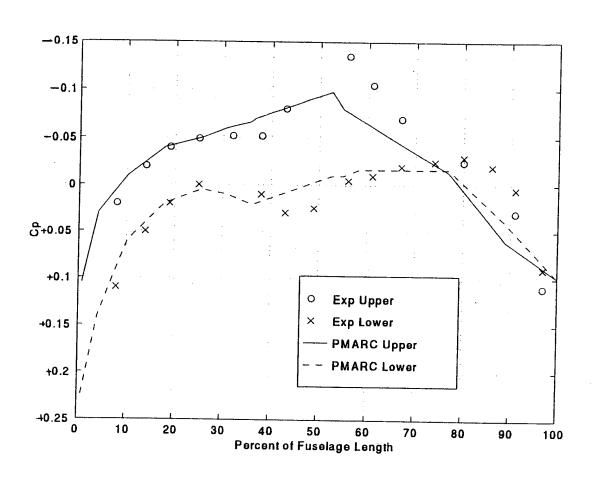


Figure 3.2 Comparison of Cp Data Along Fuselage Centerline (AOA=4°), After Ref. [8].

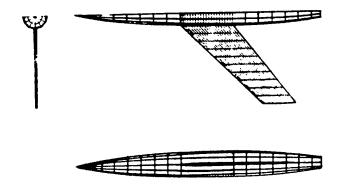


Figure 3.3 Wing-Body Panel Geometry, From Ref. [9].

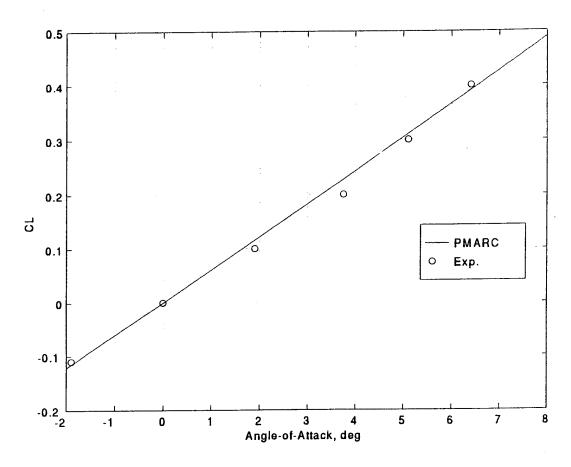


Figure 3.4 Comparison of Wing-Body C<sub>L</sub>, After Ref. [9].

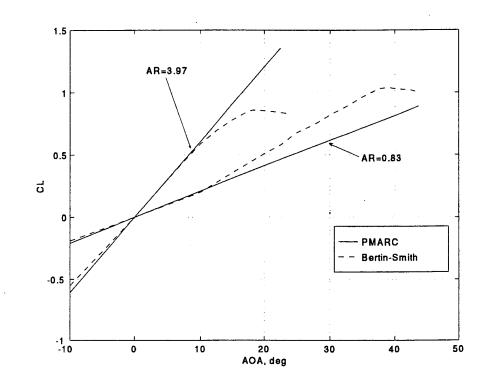


Figure 3.5 Delta Wing C<sub>L</sub> Comparison (thickness=0.12c), After Ref. [10].

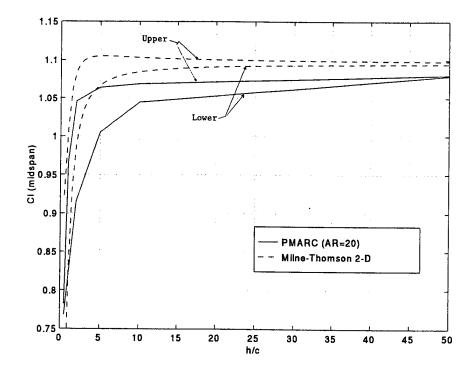


Figure 3.6 Upper and Lower Wing Mid-span C<sub>1</sub> for Unstaggered Biwings, After Ref. [11].

# 4. Wings in Ground Plane Effect

The PMARC code has an internal capability to model the ground plane. This is a fairly simple task in a potential flow code since modeling a ground plane consists only of creating a symmetric model image and placing it the appropriate distance away. Difficulties are encountered in attempting to use the PMARC internal ground plane model. The data generated by PMARC in this case is not consistent with existing data. Eventually, for this analysis, a symmetric wing is modeled and placed at the appropriate distance away from the original wing in order to generate a ground plane model. The results prove reasonable as seen in the comparison made to Kohlman's data [Ref. 12] in Figure 3.7. Kohlman's data is generated from a simplified analysis based on a single horseshoe vortex.

In Kohlman's data, an increase is seen in the lift coefficient ratio at lower AOA while the wing is flying near the ground. As the AOA is increased, the lift coefficient ratio is adversely affected and in fact can be seen to fall below the no-interference lift coefficient. Although the exact  $C_L$ 's are not compared, the PMARC data in general matches the Kohlman's results fairly well.

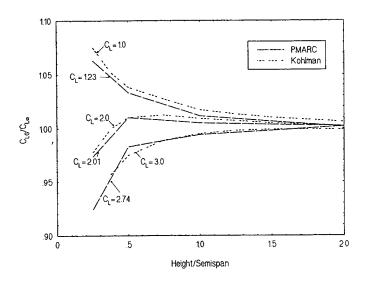


Figure 3.7 Wing in Ground Effect Comparison (NACA0007 Rectangular Wing, AR=7), After Ref. [12].

#### **B. UNSTEADY FLOW COMPARISONS**

Several comparisons are made between PMARC results and published results for oscillating wings, wings in impulsively started flows, and the wake interactions of tandem wings.

# 1. Pitching Wing Comparisons

Comparisons of results for wings executing harmonic pitch oscillations are made between an aspect ratio 20 wing in PMARC, Theodorsen's two-dimensional analysis [Refs. 13, 17], and the NPS two-dimensional, unsteady, panel code [Refs. 14, 15, 16]. Martin and Kroo [Ref. 13] actually make comparisons between Theodorsen's two-dimensional equations [Ref. 17] for an airfoil in pitch and plunge motion and their own runs using the PMARC code. The equation presented in Ref. [13] for the moment coefficient of a two-dimensional airfoil oscillating in pitch only is found to be in error. There is an erroneous negative sign in the first term of the equation. The corrected pitching moment equation is:

$$(C_m(t))_p = \frac{\pi}{2} \alpha_0 [(a-0.5)k + 2(0.5+a)((0.5-a)kF + G]\cos(\omega t) + \frac{\pi}{2} \alpha_0 [(0.125+a^2)k^2 + 2(0.5+a)(F - (0.5-a)kG]\sin(\omega t)]$$
(3.1)

The lift coefficient equation for a two-dimensional airfoil in pitch only is:

$$(C_{I}(t))_{p} = \pi \alpha_{0} [k + 2(F(0.5 - a)k + G)] \cos(\omega t) + \pi \alpha_{0} [ak^{2} + 2(F - (0.5 - a)Gk] \sin(\omega t)$$
(3.2)

The "F" and "G" terms in Equations 3.1 and 3.2 are the real and imaginary components from the Theodorsen function, and " $\alpha_0$ " is the pitch motion amplitude in radians. The reduced frequency "k" is equal to  $\omega b/U_{\infty}$  with "b" being the airfoil half-chord, and "a" is the location of the pitching axis [Ref. 13]. Martin and Kroo examine many different parameters in their analysis of unsteady wing motions. The principal goal of this comparison is to consider the lift and pitching moment coefficients for a wing pitching about its one-half chord point.

Shown in Figure 3.8 is the comparison between Theodorsen's equations and the resulting PMARC data at a reduced frequency of k=0.3. The lift and pitching moment coefficients are matched fairly well. Shown in Figure 3.9 is the comparison between the PMARC results and those obtained by the NPS code for lift coefficient and moment coefficient at a reduced frequency of k=0.3. This comparison shows good agreement.

# 2. Impulsively Started Wings

The PMARC code inherently starts all runs with an impulsive start unless otherwise directed. Martin and Kroo [Ref. 13] make a brief comparison of an impulsively started rectangular wing with an aspect ratio of 6. Katz and Plotkin [Ref. 18] investigate impulsively started wings for the case of several different aspect ratios of rectangular wings and compare them with other potential flow computer codes. Shown in Figure 3.10 are indicial  $C_L$  results computed with PMARC compared to the results from Katz and Plotkin. Shown in Figure 3.11 are the induced drag coefficient ( $C_{Di}$ ) comparison. An AGARD report by Lomax [Ref. 19] presents indicial lift coefficients for impulsively started wings for rectangular and delta wings. Shown in Figure 3.12 are the rectangular wing  $C_L$  comparison between Lomax and the PMARC results. Figure 3.13 provides the  $C_L$  comparison for an aspect ratio 4 delta wing. Actually Lomax plots lift curve slope ratios instead of lift coefficient ratios, but for low AOA the ratios are essentially the same as the dependence on AOA will cancel out.

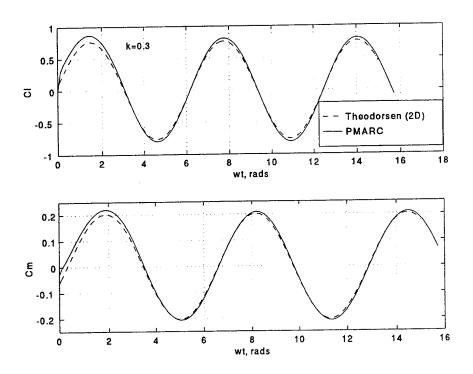


Figure 3.8 Oscillating Wing Coefficient Comparisons to Theodorsen's Equations for NACA 0007, AR=20 Rectangular Wing Pitching at the c/2 axis, After Ref. [13].

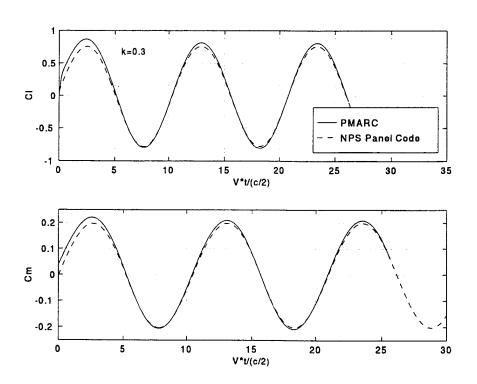


Figure 3.9 Oscillating Wing Coefficient Comparisons to the NPS Panel Code for NACA 0007, AR=20 Rectangular Wing Pitching at the c/2 axis, After Ref. [16].

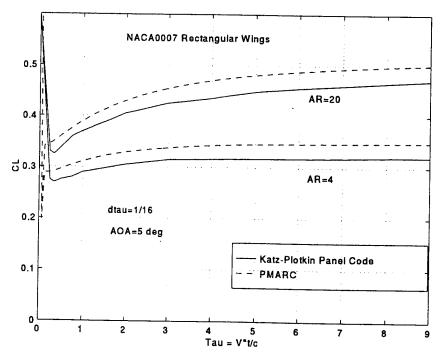


Figure 3.10 C<sub>L</sub> Comparisons for Impulsively Started Wings, After Ref. [18].

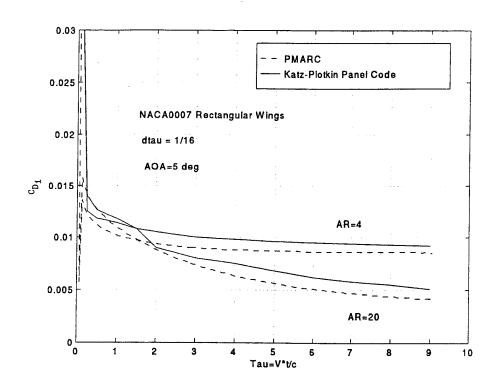


Figure 3.11 Induced C<sub>D</sub> Comparison for an Impulsively Started Wing, After Ref. [18].

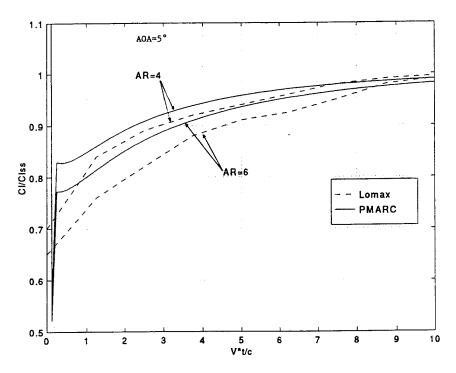


Figure 3.12 Impulsively Started Lift Coefficient Ratio Comparison for AR = 4 and 6, NACA 0007, Rectangular Wings, After Ref. [19].

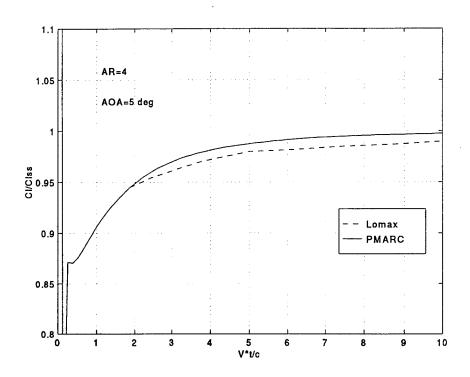


Figure 3.13 Impulsively Started Lift Coefficient Ratio Comparison for AR = 4, NACA 0007, Delta Wing, After Ref. [19].

# 3. Wings in Tandem

A comparison is made to an analysis of a two-dimensional pair of airfoils flying in tandem as shown by Glauert [Ref. 20]. The theoretical results predicted by Glauert for the two dimensional case indicate that an airfoil having a chord length twice that of each individual airfoil set in tandem has the average lift coefficient of the tandem pair as shown in Equation 3.3:

$$C_{L_{2c}} = \frac{C_{L_{FWD}} + C_{L_{AFT}}}{2}$$
 (3.3)

Attempts to model this exact geometry in a three-dimensional configuration using the PMARC code meet with mixed results. The problem found is that the wake being convected downstream from the forward wing impinged upon the aft wing and penetrate the aft wing's surface during the subsequent time step. Therefore, the cases studied are those that avoided this

penetration. Jones and Platzer [Ref. 16] find for a two-dimensional wake interaction computer code that by decreasing the time step to very small relative values the convected wake will avoid the aft wing. This approached proves to be computationally unreasonable for the three-dimensional PMARC code.

Two cases are devised where the forward wing's wake passes close to the aft wing but does not actually touch it. In each case two wings are placed in tandem separated by three chord lengths measured from leading edge to leading edge. The first case places the wing system at a global AOA of 10° so that the forward wing wake passes over the aft wing. The  $C_L$ 's are compared for the developing flow of the first case in Figure 3.14. In the second case, the aft wing is shifted 0.2 chord lengths above the forward wing, and each individual wing is placed at an AOA of 10° so that the forward wing wake passes below the aft wing. The  $C_L$  comparison of the second case is shown in Figure 3.15. The resulting mid-span section lift coefficients are compared to a single wing with twice the chord length of each individual wing. Wings with aspect ratios of 6 and 20 are compared although only aspect ratio 6 wings are shown in Figures 3.14 and 3.15. Table 3.1 compares the resulting values from the PMARC runs for the section lift coefficients.

AR	C <sub>1</sub> for 2x Chord	Average C <sub>1</sub> for Global	Average C <sub>1</sub> for Aft
	Single Wing	AOA of 10°	Wing Shifted +0.2c
6	0.9035	0.7595	0.7419
20	1.0639	0.9969	1.0047

Table 3.1 Tandem Wings Average Section Lift Coefficient Comparisons.

The average section lift coefficients shown in Table 3.1 are calculated from the section lift coefficients from the forward wing and the aft wing as shown in Equation 3.1. The pair of wings with aspect ratio 20 have a section lift coefficient closer to the theoretical value predicted by Glauert than the aspect ratio 6 pair. Also, some deviation from theory is to be expected since it is not possible to follow the exact geometry presented by Glauert.

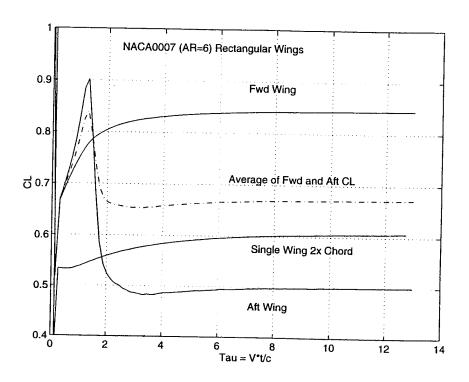


Figure 3.14 Two Wings in Tandem at a Global AOA of 10°, Separated by Three Chord Lengths Leading Edge to Leading Edge, After Ref. [20].

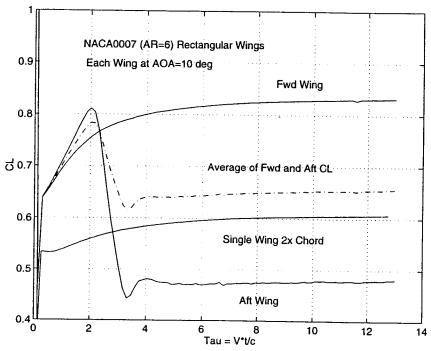


Figure 3.15 Two Wings in Tandem with the Aft Wing Three Chord Lengths (Leading Edge to Leading Edge) Behind and Shifted 0.2 Chord Lengths Up, After Ref. [20].

#### V. RESULTS OF MISSILE MODELING

#### A. MISSILE AIRFRAME DISCUSSION

The primary focus of the remaining work is to evaluate PMARC for aerodynamic missile design. To this end, the missile configurations studied by Smith et. at., [Refs. 21, 22] and by Meyer [Ref. 23] are investigated. Smith carries out a series of Mach 0.2 wind tunnel experiments on the configuration seen in Figure 4.1a. The PMARC model is shown in Figure 4.1b. Normal, moment, and axial force coefficients are found as a function of AOA. Additional parameters considered are control surface deflection and missile roll angle. Similarly, Meyer conducts wind tunnel experiments at Mach 0.1 on the configuration seen in Figure 4.2a. His primary concern centers on the effects of wing location and missile roll angle on various force coefficients. The PMARC model of the Meyer wing-body is seen in Figure 4.2b.

#### B. AERODYNAMIC COEFFICIENTS

A large emphasis is made in validating the aerodynamic coefficients presented in Refs. [21, 22, 23]. Meyer [Ref. 23] provides a comprehensive set of data with which to compare experimental values to PMARC generated coefficients like the pressure coefficient (Cp) and the normal force coefficient (C<sub>N</sub>) for the missile wings and body. It is more difficult for PMARC to match the coefficients for the configuration used by Smith [Ref. 21, 22] due to canard-tail-body flow interactions. The wake modeling provided by PMARC is not found to be robust in terms of dealing with downstream interactions from other components of the body geometry. Application of the PMARC wake mechanism provide the most difficult aspect of modeling the flows although some reasonable coefficient values are obtained by applying vortex sheet type wakes to the models as discussed below.

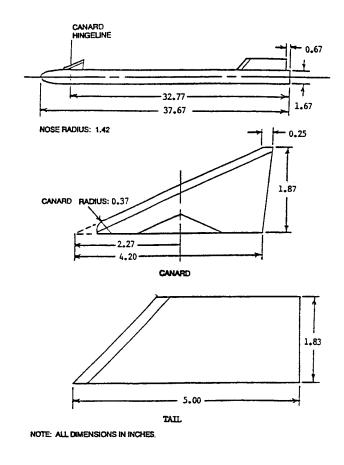


Figure 4.1a One-Third Scaled Missile Model Used for Experiments, From Ref. [21].

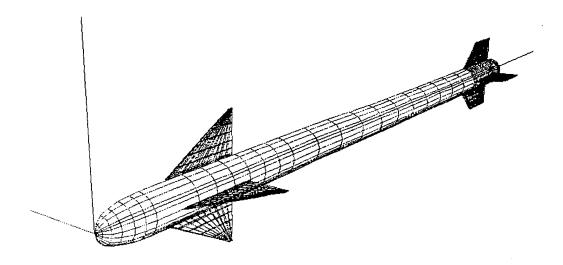
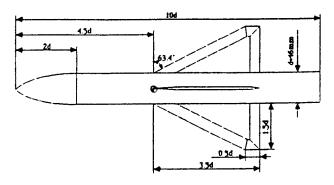
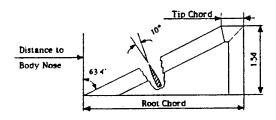


Figure 4.1b PMARC Panel Model of Smith's Missile.



Wing B - Mid Position Configuration



Configuration	Distance to Nose	Root Chord	Tip Chord
Wing A - Mid Position	4 5d	3 0d	0
Wing B - Fore Position	2.4d	3 5d	0.5d
Wing B - Mid Position	4.5d	3 5d	0.5d
Wing B - Back Position	6 0d	3 5d	0 5d
Wing C - Mid Position	4.5d	4.0d	1 0 d

Figure 4.2a Meyer Wing-Body Model Used for Experiments, From Ref. [22].

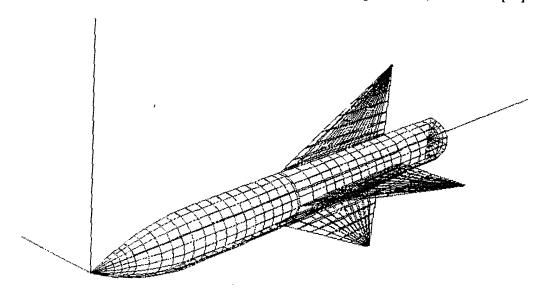


Figure 4.2b PMARC Panel Model of Meyer's Configuration.

# 1. Pressure Coefficient (Cp)

Comparison of the PMARC generated Cp distribution around an axisymmetric body to other data and theories provides insight to the accuracy of PMARC.

### a. Nose Geometry

Many general theories predicting the pressure distribution over bodies are functions of the local slope along the bodies. Theoretical analysis of the Meyer body (Figure 4.2) and the pressure distribution around it requires that the nose geometry be mathematically defined. The nose on this body is a tangent-ogive. This is a fairly common nose configuration on many types of air-to-air missiles. A general equation [Ref. 24] used to define a tangent-ogive for missile applications is:

$$y(x) = \sqrt{R^2 - (x - L)^2} - b$$
 (4.1)

For the case of the Meyer body with a nose length of 2d (L = 0.3018 ft) based on a body diameter of 0.1509 ft, the parameters in Equation 4.1 are R = 0.6414 ft, and b = 0.5659 ft. These parameters are found by applying the following boundary conditions to Equation 4.1.

$$y(0) = 0$$
 (4.2a)

$$y(L) = d/2 (4.2b)$$

Figure 4.3 shows the general geometry for a tangent-ogive nose described by Equation 4.1.

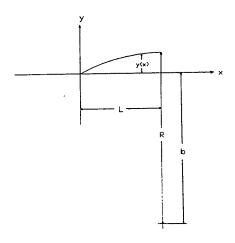


Figure 4.3 Tangent-Ogive Nose Geometry.

## b. First Order Slender Body Theory

First order Slender Body Theory (SBT) predicts a Cp distribution that is linear in AOA about a body of revolution at low AOA. Equation 4.3 represents the first order equation for the Cp about a slender body [Ref. 25]. The  $\theta$  body angle is referenced to zero at the six o'clock position looking at the body from the nose to the tail.

$$Cp(x) = 4\alpha y'(x)\cos(\theta)$$
 (4.3)

For the example of the ogive nose for the Meyer body, the equation for y'(x) results from taking the derivative of Equation 4.1 which describes the shape of the nose. The derivative of Equation 4.1 gives the local slope of the ogive nose.

Shown in Figure 4.4 is the Cp comparison along the length of the body from first order SBT results to those of PMARC for the Meyer body-alone. The PMARC results are concluded to be more accurate than SBT near the nose. As seen in Figure 4.4, first order SBT predicts zero Cp at AOA when the slope of the body relative to the body axis is zero.

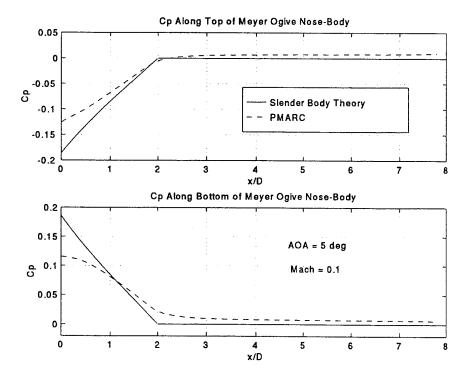


Figure 4.4 Cp Comparison Along Top and Bottom of the Meyer Body-Alone, After Ref. [24].

First order SBT only predicts pressure disturbances resulting from AOA effects. Hence at zero AOA, SBT predicts a zero pressure distribution as seen in Equation 4.3. In contrast, PMARC calculates the pressure distribution from body thickness effects as well as AOA effects. In order to make a comparison between the SBT and PMARC results, the thickness effects must be subtracted out of the PMARC results. This is done by running the body in PMARC at zero AOA, and then running it at the desired AOA (e.g., 5°). Now the Cp resulting from just AOA effects is essentially the Cp from the run at AOA minus the Cp resulting from the zero AOA run. The Cp from the zero AOA run is actually the pressure distribution generated from the body thickness effects. By subtracting its value, the remaining Cp is due to AOA effects as seen in Equation 4.4.

$$Cp_{\alpha} = Cp_{TOTAL} - Cp_{THICKNESS}$$
 (4.4)

For the Meyer body with a tangent-ogive nose of length x/d=2, the Cp expression from first order SBT is seen in Equation 4.5.

$$Cp(x) = 4\alpha \cos(\theta) \frac{(L-x)}{\sqrt{R^2 - (x-L)^2}} \quad \text{for } x \le 2d$$
 (4.5a)

$$Cp(x) = 0$$
 for  $x \ge 2d$ . (4.5b)

# c. Second Order Slender Body Theory

As seen in Figure 4.5, the Cp comparison along the mid-line of the Meyer body. Obviously, the second order SBT is not matching the Cp very well near the nose of the body as it cannot account for all the disturbances that PMARC models. Equation 4.6 shows the second order theory [Refs. 25, 27]. In this case, the  $\theta$  body angle is referenced from the three o'clock position looking at the body from the nose to the tail. This is different from the first order theory equation and needs to be kept in mind when comparing the two equations.

$$Cp(x) = -4\alpha y'(x)\sin(\theta) + \alpha^{2}[1 - 4\cos^{2}(\theta)]$$
 (4.6)

The same local slope equation y'(x) applies to the second order Equation 4.6 as it does for the first order Equation 4.5.

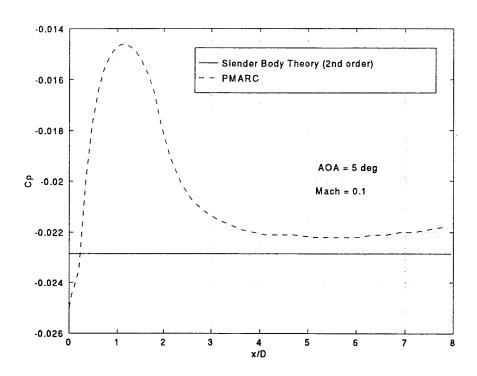


Figure 4.5 The Cp Comparison Along the Mid-line of the Meyer Body-Alone, After Ref. [23].

# d. Experimental Data Comparison

Mendenhall et. al. [Ref. 26] provides data describing the Cp distribution around the body at different fuselage stations. The Mendenhall data is for a tangent-ogive nose-body with a nose length of x/d=3 and a body length of x/d=7.7. In this data, the  $\beta$  body angle is referenced to zero at the six o'clock position looking at the body from the nose to the tail. A comparison of the Cp distribution with the PMARC data generated at different locations along the body from PMARC is shown in Figures 4.6 and 4.7. Fair agreement is seen near the nose of the body. The agreement breaks down toward the tail of the body as nonlinear flow effects and separated flow begin to dominate.

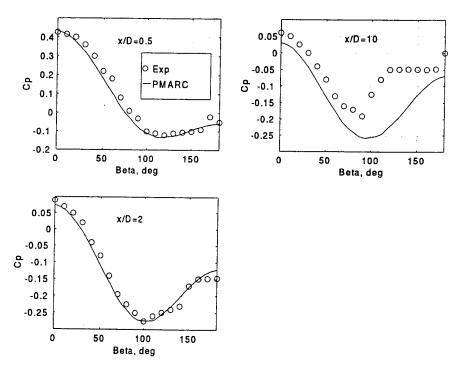


Figure 4.6 Cp Comparison for AOA=15° at Mach=0.3 of Body of Revolution, After Ref. [26].

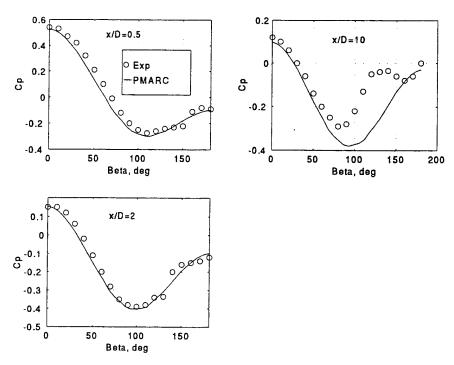


Figure 4.7 Cp Comparison for AOA=20° at Mach=0.3 of Body of Revolution, After Ref. [26].

# 2. Normal Force Coefficient (C<sub>N</sub>) From Initial Wake Model

The two configurations shown in Figures 4.1 and 4.2 are initially analyzed using a simplified wake model. This wake model consists of wakes shed from the horizontal control surfaces as well as a circular-shaped wake shed from the blunt tail. This wake model proves to be inadequate for PMARC to properly calculate the C<sub>N</sub> values. A more accurate wake model is discussed in a later section. Even though inaccurate, the results from the initial modeling attempts are still of interest, and the following is a discussion of the results.

As seen in Figure 4.8 the comparison between Meyer's data [Ref. 23] and PMARC shows general agreement at relatively low AOA for  $C_N$  of the total wing-body system at a zero roll angle ( $\phi$ =0°). This configuration has large wings relative to body diameter. The wings generate the majority of the lifting force in this case which is modeled well by PMARC. Figure 4.9 shows the  $C_N$  comparison for the body-alone case. Apparently, the PMARC model is not accounting properly for the lift due to the body. In the later section on wake modeling a more accurate method to predict body lift is discussed. Figure 4.10 shows the  $C_N$  comparison for the wings in the presence of the body, and the body in the presence of the wings. These results are matched reasonable well at low AOA due to the presence of the wings and the lift they produce.

The C<sub>N</sub> curve for the Smith missile configuration seen in Figure 4.11 shows that PMARC underpredicts the values compared to Smith's experimental values [Refs. 21, 22] and the AP95 data [Ref. 28]. Most likely the lift due to the body is not being fully accounted for similar to the Meyer body-alone as discussed previously. The Smith missile has small wing surfaces consistent with most tactical missiles. In this case, the majority of the lifting force comes from body lift. Since the PMARC model devised for the Smith missile does not model the body lift well, the deviation between the experimental C<sub>N</sub> and the PMARC prediction is relatively large. In the wake modeling section to follow, a discussion is made of the use of vortex sheet wake separation lines along the body to better model the body lift contribution as well as the use of wakes shed from the canards and tail surfaces to account for the lift contribution from these components.

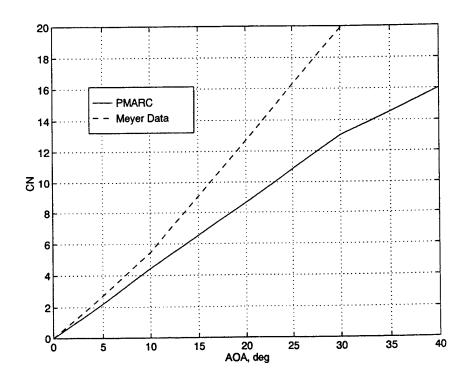


Figure 4.8 C<sub>N</sub> for Total Wing-Body System at Zero Roll Angle, After Ref. [23].

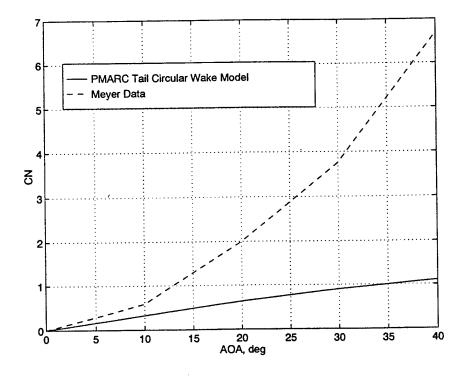


Figure 4.9  $C_N$  Comparison for Body-Alone, After Ref. [23].

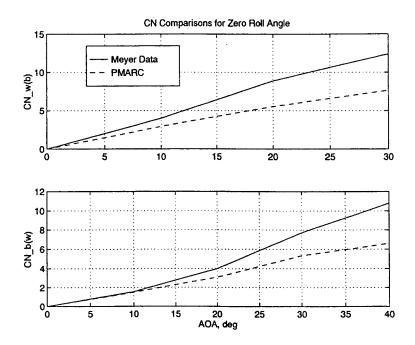


Figure 4.10  $C_N$  Comparison for the Wing in the Presence of the Body ( $C_N$ \_w(b)) and the Body in the Presence of the Wing ( $C_N$ \_b(w)), After Ref. [23].

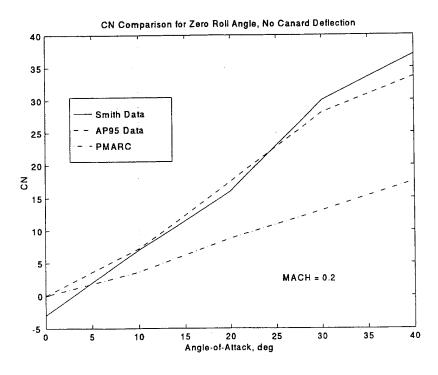


Figure 4.11  $C_N$  Comparison of a Canard-Controlled Missile, After Ref. [21, 28].

## C. WAKE MODELING

The wake modeling in PMARC is the principal component in predicting the lift force contributions of individual body components. For a basic wing model, the wake mechanism is well understood, and a shed wake is placed at the trailing edge of the wing. This type of configuration usually results in close comparisons between the lift on the wing from PMARC and other published values. In contrast, the case of a missile body with canard and tail surfaces proves more difficult in modeling an accurate wake shedding system. A majority of the wake modeling effort centers around the Meyer body-alone configuration. This configuration provides a good test base to validate the different wake modeling schemes attempted. More on this wake modeling effort follows in the next section.

It is felt more work could be done on enhancing the PMARC body lift component to further improve the correlation between the PMARC results and those from experimental methods. There is apparently a trade-off in accuracy in the modeling of the wake shed from the body. This wake shedding is the mechanism for generating lift forces in PMARC. For the cruciform missile bodies at a 0° roll angle, or in the "plus" configuration, only the horizontal control surfaces are assigned wakes since the vertical surfaces are assumed to contribute no lift to the missile system.

The wake model for the Meyer missile at a 45° roll angle, or in the "X" configuration, requires that each of the four wings shed a wake since each wing is generating lift in that orientation. Consequently, the lower two wings have wakes which penetrate the aft fuselage when the missile is placed at an AOA. This meant that these two wakes have to be truncated on each trailing edge so they will just miss the fuselage at a given AOA as they convect downstream. This causes the lift for those particular wings to be underpredicted. The alternatives in this configuration are having the wakes from the lower two wings extend along the entire wing trailing edge and penetrate the aft fuselage or truncate the trailing edge wakes causing the lift contribution from the wings to be underpredicted.

PMARC has two options within its wake model. There is the option to have a rigid wake or a flexible wake. A rigid wake is convected at the free stream velocity and is transported downstream with no distortion of the wake panel. A flexible wake is convected with the local velocity field and provides modeling of vortex roll-up as seen, for example, in a wing tip vortex

system. The flexible wake is more computationally intensive than the rigid wake and is more prone to cause problems in running a model.

### 1. Vortex Sheet Separation Line for the Meyer Body-Alone

In this analysis, two wake models are used in PMARC for the Meyer body-alone configuration that allowed for stable computations. The previously discussed first wake model attempted for the Meyer body-alone consists of a circular-shaped wake shed from around the edge of the blunt tail. The second wake model places two vortex sheet wake separation lines along the length of the body at general locations consistent with published vortex separation lines [Refs. 26, 27]. This second wake model provides a large amount of flexibility in controlling the  $C_N$  calculated by PMARC. The PMARC model for the Meyer body-alone consists of 2940 panels with 60 panels placed circumferentially and 49 panels placed axially. The discretization of the body is largely at the discretion of the user. This relatively large number of circumferential panels allowed flexibility with selecting wake separation lines. For the Meyer body-alone, two wake separation lines are started at the tangent point of the nose and body and continued back to the corner of the blunt tail. This is done in an attempt to simulate the actual location of the vortex shedding indicated in Refs. [26, 27].

Figure 4.12 is an excerpt from a DATA5 input file seen in Appendix E for the Meyer body-alone at an AOA of 20°. The parameters in the wake section allow the user to control the location of the wake shed line in any arbitrary manner consistent with the panel geometry.

	IDWAK=1, ELAGE WAKE	IFLXW=1,	ITRFTZ= 1,	INTRW= 0,	&END
	KWPACH=1, KWPAN2=44,	KWSIDE=2, NODEW=3,	KWLINE=19, INITIAL=0,	KWPAN1=19,	&END
	IDWAK=1, LAGE WAKE	IFLXW=1,	ITRFTZ= 1,	INTRW= 0,	&END
-	KWPACH=2, KWPAN2=44,	KWSIDE=2, NODEW=5,	KWLINE=11, INITIAL=0,	KWPAN1=19,	&END

Figure 4.12 Excerpt of Wake Input Parameters from a DATA5 Input File.

The KWPAN1=19 parameter indicates the wake line begins at section 19. This corresponds to the tangent point of the nose and body (i.e., there are 19 axial sections used to define the tangent-ogive nose). KWPAN2=44 indicates the wake line ends at the corner of the blunt tail which corresponds to section 44. For reference, section one is at the nose and section 49 is the last section at the tail. Figure 4.13 shows the Meyer body with wake panels being shed along the vortex sheet separation lines that are specified in the DATA5 input file for this model at an AOA of 10°. The gray-scale representation of the body in Figure 4.13 corresponds to the pressure distribution around the body for the particular time step.

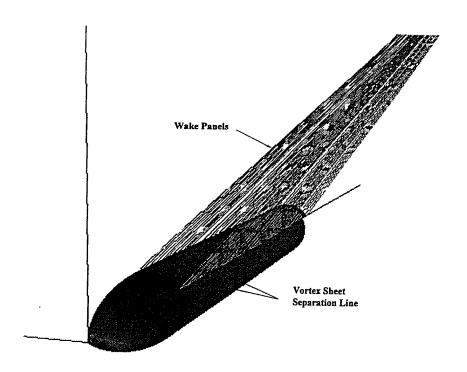


Figure 4.13 Meyer Body-Alone with Symmetric Vortex Separation Lines (AOA=10°).

The KWLINE parameter indicates where along the circumference of the body the wake separation line is positioned. The positive-Y side of the body is divided into 30 axial lines as is the negative-Y side of the body. The positive-Y side starts with line one at the bottom of the body and increments clockwise (looking nose to tail) to the top of the body at line 30. The negative-Y side starts with its line 1 at the top of the body and increments clockwise to the

bottom at its line 30 resulting in a total of 60 increments around the circumference of the body. The separation lines for the body shown in Figure 4.13 correspond to a KWLINE=17 for the positive-Y side of the body, and KWLINE=13 for the negative-Y side of the body.

With the PMARC method of modeling a lifting body, it requires the user to predict the location of body vortex separation line before actually running the code. For the comparison seen in Figure 4.14, the general locations of the vortex separation lines are initially guessed at using information from Refs. [26, 27], and then they are moved in an iterative process until the  $C_N$  values matched the experimental data from Ref. [23]. Obviously this type of process is mostly limited to investigating configurations where the coefficients are known from previous experimental or computational data. Analysis of incompletely studied configurations is possible based on some understanding of the physics of the flow and predicting the vortex separation lines from a boundary layer analysis or from Navier-Stokes computations.

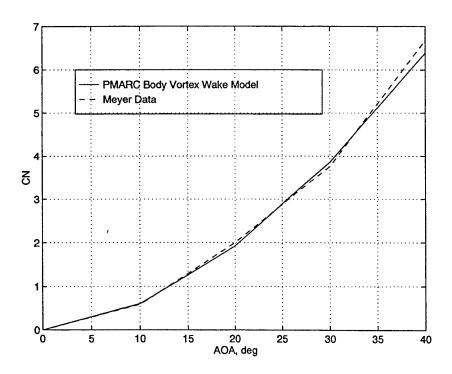


Figure 4.14 C<sub>N</sub> Comparison for the Body-Alone, After Ref. [23].

# 2. Vortex Sheet Separation Line for the Smith Canard-Controlled Missile

In this analysis, two wake models are used in PMARC for the Smith missile that allowed for stable computations. The previously discussed first wake model attempt for the missile consists of wakes shed from each of the horizontal canard and tail surfaces as well as a circular-shaped wake shed from around the edge of the blunt tail. The second wake model places wakes at the control surfaces and also two vortex sheet wake separation lines along the length of the body at locations generally consistent with published vortex separation lines [Refs. 26, 27].

A representation of the PMARC model showing the wake panels and vortex separation line on the body is seen in Figure 4.15. This missile model is initially constructed with only 20 panels placed circumferentially around the body. Time constraints do not allow a more finely meshed model to be created. The existing panel distribution does not allow a large amount of flexibility in placing the vortex sheet separation line. Hence, as seen in Figure 4.16, the  $C_N$  values calculated with PMARC are not as close to the experimental data as those that are obtained for the Meyer body-alone due to its finer panel discretization.

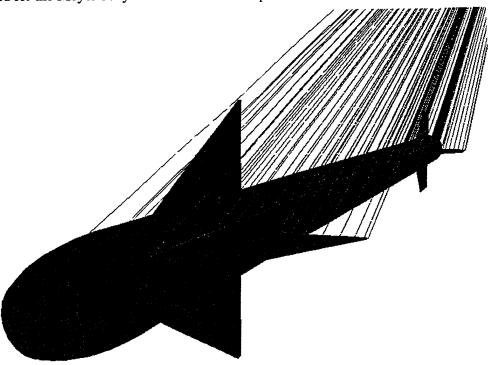


Figure 4.15 Smith Missile with Symmetric Vortex Separation Lines (AOA=20°).

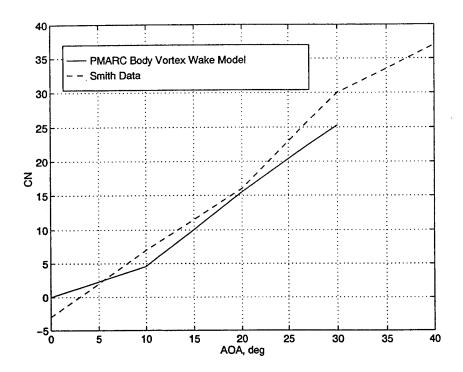


Figure 4.16 C<sub>N</sub> Comparison of a Canard-Controlled Missile, After Ref. [21, 28].

Comparisons are also made of the pitching moment coefficient ( $C_M$ ) from PMARC and those from experiments for the Smith missile. The PMARC  $C_M$  results are seen to be widely scattered and not within reasonable variation from the values published in Ref. [21], and therefore are not deemed meaningful enough to plot. Apparently the wake model used to match the  $C_N$  values is not sufficient to also match the  $C_M$  results. This is not altogether surprising since computational matching of  $C_M$  values is typically more difficult to do than matching the force coefficients. If PMARC is to be used as a complete design tool, a more detailed wake model will undoubtedly need to be constructed in order to properly match all the coefficients if possible.

#### VI. SUMMARY AND CONCLUSIONS

The main goal of this analysis is to determine the suitability of PMARC for initial aerodynamic missile design. To accomplish this, PMARC is compared with results available from other analyses and from experiments. This allows conclusions to be drawn on the capabilities as well as the limitations of PMARC.

It is found that PMARC, in general, can properly predict results for low AOA wing configurations as is expected from a potential flow code. The fundamental mechanism for producing lift in PMARC is the shed wake modeling. This wake-shedding process is well defined for a wing model.

The unsteady capabilities explored in PMARC prove to be an accurate tool for predicting the lift and moments of oscillating wings when compared to theory and the NPS unsteady panel code. Additional investigations of more complex configurations in an oscillatory flow are needed to fully understand the limits of PMARC's unsteady capabilities. An investigation of the indicial aerodynamic capabilities of PMARC shows reasonable results when compared to other data.

Significant challenges are encountered in attempting to model the wakes shed from bodies of revolution and bodies of revolution with control surfaces. It took several iterations to develop an intuitive scheme for the calculation of lift for bodies of revolution. Finally a wake modeling scheme using vortex separation lines along the length of the body produced normal force coefficients close to experimental data. A combination of the vortex separation lines along the body and wake shedding from the tails and canards are used for the canard-controlled missile. Although the normal force coefficient values calculated with PMARC for this configuration are close to the experimental data, reasonable values for the pitching moment coefficients are not produced. A more detailed wake model would be the next direction in the study of lift producing slender bodies with control surfaces. Further work is necessary to refine this procedure for identifying the proper location of the separation lines. This information will probably need to be provided from a boundary layer analysis or Navier-Stokes calculations.

# APPENDIX A. NACA 4418 DATA5 INPUT FILE

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681095	UTSTPS= 10,	LSTNAB=0, SOLRES=0.01,	LSTFRQ=0, LSTWAK=0,	LENRUN=2, LSTCPV=0,	LPLTTP=1,	GEND GEND GEND
2011111	RSYM=1.0,	DTSTEP=0.5, RGPR=0.0,	RFF=5.0, 1	RCORES=0.0080,	RCOREW≈0.0080,	EEND EEND
4BINP8		YAWDEG=0.0, THEMAX= 0.0.	PHIDOT=0.0	, THEDOT=0.0,	PSIDOT=0.0,	GN37
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&BIMP9	WTX=0.0, CBAR=10.83,	WTY=0.0, SREF=1000.0,	WTZ=0.0, SSPAN= 50.0	.00		CEND FERIO
4B111P10	RMPX=3./5, NORSET=0,	NBCHGE=0,	MCZONE=0, VREF=0.0,			OH39
CBINP11 CBINP12 CBINP13	HOCF*0, HOCF*0, KPAH=0, NBLIT=0,	NORF=0, NOCL=0, KSIDE=0,	NORL=0, VNORM=0.0, NEWNAB=0,	NEWSID=0,		& END & END & END
4ASEM1	ASEMX=0.00, ASCAL=1.00,	ASEMY=0.00 ATHET=0.00		ASEM2=0.00, NODEA=5,		4 END
&ASEM2	APXX=0.00, AHXX=0.00,	APTY=0.0 AHTY=1.0		722=0.00, 122=0.00,		QEI1D
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4 PATCH1	IREV= 0, 11 IPATCOP=0, WING	IDPAT= 1, MAKE=	, x	= 1, KASS= 1	rsym=1,	& E11D
&SECT1	STX= 0.00 ALF= 0.0, INMODE= 5,	0.0000, STY= 0.0000, 0.0, THETA= 0.0, 5, THODS= 0, TH	STZ:	0.0000, TINTS= 0,	SCALE= 15.00 ,	& END
&SECT2		TNPC= 15, STY= 50.00,	TINTC = 0, STZ = 0.	. 8	= 5.00,	4END
	ALF= 0.0, INMODE= 0,	THETA= 0.0 TNODS= 3,	, TMPS= 19,	TINTS= 2,		4 EthD
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4 PATCH2	WING_TIP ITYP= 2,	TWODS= 5,	Tups= 4,	, TINTS= 3,		31137
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WING_WAKE &WAKE2 K	AKE KWPACH=2, KWPAN2=0,	KWSIDE=4, NODEW=0,		KWLINE=0, K INITIAL=0,		QM37
4WAKE2	KWPACH=1, KWPAN2=0,	KWSIDE=2, NODEW=5,			KWPAH1 = 0,	4 END
& ONSTRM	HONSL =0,	KPSL = 20,				4.END
& BLPARAM	M RII =3837800	0, VISC =	0.000157, NSLBL	SLBL = 1,		& END
4VS1 4VS2 4VS3 4VS4	X0= -0.1 X1= -0.1 X2= -0.1	NVOLC= 0 000, Y0= 000, Y1= 000, Y2=	1.5000, 20= 1.5000, 21= 1.5000, 22=	-0.1000, 0.1000, 0.1000,	INTVSR= 1, NPT1 = 0, NPT2 = 20,	CEND CEND CEND
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# APPENDIX B. NACA 65-412 DATA5 INPUT FILE

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	ω	2	4.500 BPNODE

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1994 14:34 NACA6digit NACA6digit	## ASPECT Relio Wing: 50ft Span, HACA-05_1-116    LSTINE2  LSTOUT=0, LSTERR=0, LEIRUNI=2, LSTURE=0, LSTURE	ASENX=0.00, ASENX=0.00, ASENX=0.00, ASEXX=0.00, ATHET=0.00, NODEN=5, APXX=0.00, APXX=0.00, APXZ=0.00, APXZ=0.00, APXZ=0.00, APXZ=0.00, APXZ=0.00, APXZ=0.00, COMPX= 0.0000,	IPEVS 0, IDPATE 1, MAKE 0, KCOMP 1, KASS 1, IPATSTM-1, MAKE 0, COMP 1, KASS 1, IPATSTM-1, MAKE 0, KCOMP 1, KASS 1, IPATSTM-1, MAKE 0, ONDO, STZ 0,0000, STZ 0,0000
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IREV=	0, IDPAT						&END
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KE						•	&END
KWPAN2	=2, =0,	KWSIDE NODEW=	=4, 0,	KWLIN INITI	E=0, AL=0,	KWPAN1=0,	&END
	=1, =0,	NODEW=	=2, 5,	INITI	AL=0,	KWPANI=U,	&END
nonsl	=0, KPSL	= 20,					&END
P.N =37	210000,	VISC	= 0.00015	7, NSL	BL = 1,		& END
MVOLR= X0= X1= X2= X3=	0, -0.1000, -0.1000, -0.1000, 1.1000,	NVOLC= YO= Y1= Y2= Y3=	0, 1.5000, 1.5000, 1.5000, 1.5000,	Z0 = Z1 = Z2 = Z3 =	-0.1000, 0.1000, 0.1000, -0.1000,	INTVSR= 1, NPT1= 0, NPT2= 20, NPT3= 25,	&END &END &END &END &END
XRO= XR1=	2.0000, 4.0000.	YR0= YR1=	2.0000,	ZR0= ZR1=	0.0000,	INTVSC= 1,	&END
XR2= R1= NRAD=	2.0000, 0.1000, 5,	YR2= R2= NPHI=	2.0000, 1.0000, 12,	ZR2 = PHI1 = NLEN=	1.0000, 0.0, 3,	PHI2=360.0,	&END &END &END
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SXU= SU= SYD=	-2.0000, 0.0000,	SY0= SD= SY0=	1.0000,	SZ0= DS= SZ0=	0.2500,	INTSL= 1,	& END
SU= SX0=	0.0000,	SD= SY0=	10.0000,	DS= S20=	0.2500, -0.3000,	INTSL= 1,	GEND
SU= SX0=	0.0000,	SD= SY0=	10.0000,	DS≥ S20=	0.2500, -0.2000,	INTSL= 1,	& END
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# APPENDIX C. CRUCIFORM WING-BODY DATA5 INPUT FILE

Page 2		GEUC	JH37	4.5110	4 E11D	4EUD	4EHD	ØE11D	4END	4END	GEI1D	G.END		# END									& END	¢ END	4 END	& EHD	& END	4EUD	0113 <b>7</b>
Jul 24 1995 10:07 DATA5	GPATCHI IREV: 0, IDPAT: 1, MAKE: 1, FCCMP: 2, KASS: 1, IPATSTW:1,	IPATCOP=0, -WING TIP		&PATCHI IREV= 0, IDPAT= 1, MAKE= 0, KCCMP= 2, KASS= 1, IDATSTM=5, IDATOP=1, IDATOP=1	&PATCH PATKS-0, PATY-80.0, PATZ-60.0, PSCAL-1.0, PTHET-90.0, NODEP-0 PPXX-0.0, PPXX-0.0, PPXX-0.0, PPXX-1.0,PHXY-0.0,PHZ2-0.0	GPATCHI IREV= 0, IDPAT= 1, MAKE= 5, KCOMP= 2, KASS= 1, IPATSIM=0, IPATCOP=0,	VERT-UP-WING TIP &PATCH2 IT:P= 1, TWODS= 3, TUPS= 1, TINTS= 3,	&PATCH1 IREV* 0, IDPAT= 1, MAKE* 0, KCCMP* 2, KASS= 1, IPATSTM=0, IPATCOP=1,	VERT-WING_DOWN  &FATCH PATX-80.0, PATY-80.0, PATZ-80.0, PSCAL=1.0, PTHET=-90.0, NODEP=0  PPXX-80.0, PPXX-80.0, PPXX-80.0, PPXX-80.0, PHXX-80.0, PPXX-80.0,	6PATCH1 IREV= 0, IDPAT= 1, MAKE= 7, KCOMP= 2, KASS= 1, IPATSYH=0, VEPT-DOMN-WITTE TTD		**PATCH1 IREV= 0, IDPAT= 2, MAKE= 0, KCOMP= 1, KASS= 1, IPATSYH=1, FORMAND FOR	&SECTI STX = 0.005 &SECTI AIF 0.00 ST2 = 0.000, SCALE 0.000,	INHODE 1, THODS 0, THPS 0, TINTS 0, 0.000 -0.075 0.0 0.0131 -0.0743 0.0 0.0259 -0.071 0.0	0485	0633	0743	0743	0578	0377	0131	PRIODE T	0.0, THETA: E: 0, TNODS: 0, 0.0164, STY: 0.00	0.0, THETA= 0.0, NE= 0, TNODS=0, TNPS=0, TINTS= 0.0328, STY= 0.0000, STZ= 0.0000,	THETA: 0 TNODS: 0, STY: 0.000	.0, THETA: 0, TNODS: 0, 656, STY: 0.00	ARTS 0.0, THETA 0.0,  KEECTI STX 0.082 STY: 0.0000, STZ: 0.0000, SCALE: 0.4852,	0.0, THEIA: 0, TNODS: 0,0980, STY: 0	0.0, THELAR 0, TNODS= 0, 1310, STY= 0.00 0.0, THETA=

ALMERAME from Meyer Iwith separate Wing i Citic Body Wakes  126, DESTEVENCY C. LETTERQAG, LETTERPED, LETTERPED, LETTERPED, LESTERBAG, LETTERPED, COSTREED, C	11. LSTCUT=0. LSTERQ=0. LEIRUNI=3. LPLTTP=1.  10. LSTUAB=-0. LSTRRQ=0. LEIRUNI=3. LPLTTP=1.  10. SOLRES=-0.055  10. O. THENAX=0.0. PHIDOT=0.0. THEDOT=0.0.  10. O. THENAX=0.0. PHIDOT=0.0. THEDOT=0.0.  10. O. MRYAC-0.0. DEMAX=0.0.  10. O. ATHET-0.00. NODEA=5.  10. O. ATHET-0.00. COMPT= 0.0000.  10. O. CENT= 0.0000. COMPT= 0.0000.  10. O. CENT= 0.0000. COMPT= 0.0000.  10. O. CENT= 0.0000. COMPT= 0.0000.  10. O. CHYT= 1.000. COMPT= 0.0000.  10. O. CHYT= 1.000. COMPT= 0.0000.  10. O. O. CHYT= 1.000. COMPT= 0.0000.  10. O. O. O. THETA= 0.0 THES= 0. TINTS= 0.  10. O. O. O. O. THES= 0. TINTS= 0.  10. O.	-5	4 EUD	QN37 QN37 QN37	4END 4END	<b>GE11D</b>	& END	GEND 6 END	eend eend eend	& END	4 END	GEND GEND		Z END	4 END		& END								EEND
ALMERANE from Meyer I with separate Winy 5 : ilc  120, CSCLERS-0.055TWAR=0, LSTTEP9-0.7  120, DTSTEP-0.055TWAR=0, LSTTEP9-0.7  11.60, TAMBES-0.0, RFF=5.0, RSDRES-0.005  11.60, TAMBES-0.0, PHIDOT=0.0, THEDOT=0.0, RTX=0.0, NTX=0.0, NTX=0.0	LETIDEM AIRFRAME from Meyer (with separate Wing & City LETIDEA, LETTERGAC, LETREGAC, LETRINGS, LETTERGAC, LETREGAC,		1,												TSYM=1,	1.000									7.
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Alkerame from Meyer I with separate trong Meyer I with separate trong Meyer I with separate trong the separate trong transfer of the separate tran	LUSTIDEAM AIRFRAME From Meyer INITh sepa LUSTIDE20, LUSTUAB-0, LUSTRAK-0, MAXIT=200, SCRES-0.0050, LUSTRAK-0, RUSTRE-0.0150, RUSTRE-0.00, RUSTRE-0.0150, RUSTRE-0.00, RUSTRE-0.000, CHYYE-0.000, CHYYE-0.000, RUSTRE-0.000, CHYYE-0.000, RUSTRE-0.000, CHYYE-0.000, CHYY			0 0	2 0		118,		NEWSID=	MZ=0.00, SEA=5, 7=0.00	,00.0=2		٠.		2, KAS		TINTS								
AINFRAME from Meyer 120, 120, 120, 120, 120, 120, 120, 120,	LETIDE 2. LSTCUT-0.  LSTSEC-0. LSTUAB-0.00  HAXTT=200, CSCLRES-0.00  HAXTT=200, CSCLRES-0.00  RSTREAD-0.05  RSTREAD-0.05  RSTREAD-0.05  RSTREAD-0.05  RSTREAD-0.05  RSTREAD-0.07  RSTREA			,   (c)	 HIDOT=0	4AX=0.0,	~ ~ ~	TONE 0,		ASE NOD	YH2 WH2		Ü		, KCOMP	*ZLS									0.0
ALREPANE F  1.10.00	LESTIBE-2, LESTE LESTIBE-2, LESTE LESTES-6, LE	e,'er		しょう じゅ	1116.0,				NEW	886	0	0.00				0.0000,	<u> </u>								2, 1161
A PART 1	LETTIPE 2, LST3EO = 0, HTST1E 2 0, HTST E		STCUT*	LSTUAB=0 SOLRES=0 DTSTEP=	VSOUND	THEMAX=0 WRY=0.0,	SREF = 0.0	NBCHGE=( CZDUB=0	NOCL=0, NOCL=0, KSIDE=0,	ASEN	AHY				1,	, STY		90000	0.0000	0.0049	.0049	6700	0049	.0049	
				E0=0, T=200, PS= 5,	EW=0.005 =111.6,	AX*0.0,	0.1509,	SET=0, PCH=0,	F=0, F=0, F=0, F=1,	(=0.00) (=1.00)	0.00		00000 = >	0000	٠,٥	0.00	, 2000 , 4,	2 10 10 1	សូសូសូ	N N N	ເດັດ	ທຸກຸ	າທູທູ	ស៊ីស៊ីស៊ី	175,

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4END 4END 8015.		ALF 0.0, INMODE 4.	THETA=	0.0, 0, TNPS= 0,	TINTS	ċ		QEI1D
i	0.742	0.0025	0.0755			;		
9854,	0.742	0.0485	97.50.0					
2000	0.742	0.0633	-0.0377			-		
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4.END	&SECT1	THODE = 3, STX = 0.0000,	Tre o	8	0.0000,	SCALE	1.000,	1
. 786		ALF 0.0, INMODE 4,	THETA=	0.0, 0, THPS= 0.	TINTS=			QE11D
OOO KEND	0.804	0.0049	-0.0755					
	000	0.0485	-0.0578					
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4 END		INMODE= 4,	TNODS	ò	TINTS	٥,		S END
,000	0.847	0.0049	-0.0755					
GND FEND	0.857	0.0485	-0.0578					
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6.611D		ALE 0.0,	THETA =	0.0,	TINTS	c		01133
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100, £END	0.891	0.0258	-0.071					
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OU GEND		0.0049	0.0755					
	1000	0.0485	0.0578					
300, *END		0.0710	0.03//					
2		0.0755	9400.0	0				
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	-	ALF= 0.0, IRMODE= 4.	THETA =	0.0, 0. TMPS= 0.	TIME	c		CEUD
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	0.978	0.0485	0.0578					
	0.978	0.0633	0.0377					
	0.978	0.0755	0.0049					
	& BPNODE	TWODE=3, STX= 0.0000.	NPC≖0, ST"= 0.	TINTC=0, 0000, STZ= (	9,0000,	SCALE	1.500.	& EIID
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		0.0049	0.0755	o, inpos o,	*SIMIL	· .		21122
é END	1.021	0.0258	0.071					
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01137	1.021	0.0755	10000	0-04114				
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	10.50	IUMODE 4.	FINODS	0,, THPS= 0,	TIME	ڻ' ن		4 EHD
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*E80	7.	-						

Page 3	4EIID	46110	45110	4 END	4 END	4 END	4 END	e END	dn37	* 1500	gend gend	& END	e END	4 END	ZEND.	4END	GEND		-	_		46110	Q END		J1137		4END
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	,0000	o 0000	0000	000		,0000.				TNODS 0, 1	TNODS* 0, 1 STY* 0.0000,	,0000.	, 0,0 0,000	0000	0000	0.0,	, 0.0, 3, 0.0					TINTC=3	MAKE= 0,	.0000.			THIT.
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Jul 24 19	&SECT1	&SECT1	4SECT1	&SECT1	&SECT1	&SECT1	&SECT1	&SECT1	&SECT1	&SECT1	4.SECT1	4SECT1	&SECT1	4SECT1	4SECT1	4SECT1	676	0.679	0.679	0.679	0.679	ы	&PATCH1	LOWER 4.SECT1 S			0.679 0.679 &BPNODE &SECT1

lul 24 1995 10:07	55 10:07		DATAS	15			Page 5	•	2
	0.0710	0.0258					!	&BPHODE &SECT1	STX=
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UPPER	ER AFT FUSELAG STX= 0.0000,	TY≖ O	=ZTZ= ,0000	0.0000.0	SCALE	1.000,		1.021	000
	ALF= 0.0, INMODE= 4,	HETA= Nods=	0.0, 0, TNPS= 0,	TINTS=	٥,		& END	1.021 &BPNODE	TNO
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0.679 &BPNODE &SECT1	0.0 TNODE=3, STX= 0.0000	0.0755 TNPC=0, STY= 0.0	000	0.0000,	SCALE	1.000,	4.END	1.064	000
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95 10.07  10.015  10.0	Jul 24 1995 10:07 DATA5	4BHF0DE THIDDE=3, THPC=0, TINC=0, 4BECT1 STX= 0.0000, SCALE= 1.000, 48ECT1 STX= 0.0000, STY= 0.0000,		0.891 0.0755 0.0047 0.891 0.0710 0.0258		0.0659 0.0755 0.0069 0.0755 or THADREAL TRIPCEO.	&SECTI NIE 0.0000, STY 0.0000, STE 0.0000, SCALE 1.000,	INMODE 4, TWODS 0, THPS 0, THPS 0,	0.934 0.0710 0.0258	0.934 0.0633 0.0578 0.934 0.0485 0.0578	0.934 0.0258 0.071	(BPNODE TWODE=1, TNPC=0, TINTC=0, STZ= 0.0000, SCALE= 1.000,	ALF= 0.0, THETA= 0.0,	INMODE= 4, TNODS= 0, INFS= 0, 0.0755 0.0049	0.978 0.0710 0.0258 0.978 0.0633 0.0377	0.978 0.0485 0.0578 0.978 0.0258 0.071	0.0049 0.0755 TMODE=3. TNPC=0, TINTC=0,	STX= 0.0000, STY= 0.0000, STZ= 0.0000,	INNOES 4, TWODS 0, THPS 0, TIMTS 0,	1.021 0.0755 0.0049	1.021 0.085 0.0578	1.021 0.0258 0.071	EBNODE TWODE=1, TWPC=0, TINTC=0, 0.0000, SCALE= 1.000,	ALE 0.0, THEIA 0.0, MINES 0 TIMES 0	INMODE= 4, INCDS= 0, INFS= 0, INTS= 0, 0.0755 0.0049	1.064 0.0710 0.0258	1.064 0.0288 0.0578	0.0049 0.0755 TNODE=3, THPC=0, TINTC=0,	STX= 0.0000, STY= 0.0000, STZ= 0.0000,	TIMTS= 0, TIMTS=	1.107 0.0710 0.0258	1.107 0.0485 0.0578	1.107 0.0049 0.071	&BRNODE TNODE=3, TNPC=0, TINTC=0, &SECT1 STX= 0.0000, STALE= 1.030,	ALF= 0.0, THETA= 0.0, INMODE= 4, TNODS= 0, THPS= 0, TINTS= 0,	0.0755 0.0049	1.151 0.0633 0.0377	1.151 0.0258 0.071	L.13. THORES. THRESE, TIMES. STZ= 0.0000, SCALE= 1.930, STZ= 0.0000, STZ= 0.0000, STZ= 0.0000,	ALF= 0.0, THETA= 0.0, INHODE= 4, TRODS= 3, THPS= 0, TINTS= 0,	1.207 0.075 0.00 1.207 0.0710 0.0258
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Page 6

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INTRW= 1, KWPAH1=0, KWPAH1=0,

KWLINE=6, INITIAL=0, KWLINE=6, INITIAL=0,

IFLXW=1, KWSIDE=4, HODEM=3, IFLXW=1, KWSIDE=1, HODEW=0, KWSIDE=1, HODEW=5,

GEI1D GH37

VISC = 0.00016, NSLBL = 1,2,3,

NOUSL =0, KPSL = 20,50,80,

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KWPAH1=0,

INTRW= 1, KWPAH1=C,

KWLINE=0, INITIAL=0, ITRFTC= 1, KWLINE=0, INITIAL=0, ITRFTZ= 1,

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Jul 24 1995 10:07	WING_WAKE KWPACH=1, KWPAN2=0,	LEFT_MING_MAKE LEFT_MING_MAKE LAMAKE	<pre>dWAKE1 IEWAK=1,    CIRC_AFT_BODY_WAKE</pre>	&WAKE2 KWPACH=16, KWSIDE= KWPAN2=0, HODEW=5 &CNSTRM HOHSL =0, KPSL = 20,50,	4BLPARAM RN =2000000, VISC =	4VS1 NVOLR= 0, NVOLC= 0 4VS2 X0= 3.00000, Y0= 4VS3 X1= 18.0000, Y1=	x3= 3.0000,	6VS6 XR0= 0.0000, YR0= 1	0.5000,	,0000.	0000	SX0= 2.0000, SU= 0.0000,	&SLIN2 SX0= 2.0000, SY0= 50000, SY0= 10000, SY0= 100000, SY0= 10000, SY0= 100000, SY0= 10000, SY0= 100000,	,0000										
Page 7		4END	quay			ееир	4.640					<u>.</u>		4 END	4 EHD	4 END	«EIID	4.5110	01137	& END	4 END	g END	& END	4END
		IPATSYM=1,	1.000,			1.00,								= 1.00,	1.000,	1.000,	1.600,	0.800,	0.600,	0.400,	0.200,	0.000.0		INTRW= 1,
3		l, KASS= 1,	0, SCALE= TINTS= 0,			0, SCALE=	TINTS= 0,							O, SCALE=	TINTS= 0,	TINTS= 0, SCALE=	TINTS= 0,	TINTS= 0,	TINTS= 0, SCALE=	TINTS= 0,	TINTS= 0,	TINTS= 0,	TINTS= 0,	ITRFTZ= 1,
DATAS		TINTC=0, CE= 0, KCOMP= 1	STZ= 0.0000, 0, TNPS= 0,			TINTC=0, STZ= 0.0000,	. TNPS= 0,							TINTC=3, STZ= 0.000	0, TNPS= 0, STZ= 0.0000	0, TMPS= 0,	TNPS= 0, STZ= 0.0000	TNPS= 0, STZ= 0.0000	TMPS= 0, STZ= 0.0000	TNPS= 0, STZ= 0.0000	TNPS= 0, STZ= 0.0000	TNPS= 0, STZ= 0.0000	TMPS= 0,	ITRE
	0.0377 0.0578 0.071 0.0755	FNPC=0, PAT= 2, MAK	STY = 0.00, THETA = 0.0, TNODS = 0,	-0.0578 -0.0377 -0.0258	0.0258 0.0377 0.0578	0.0755 INPC=0, STY= 0.00,	TNODS 0,	0000	2000	000	200	0.0	0000	TNPC=10, STY= 0.00,	THETA 0. THODS 0, STY = 0.00,	THODS= 0, STY= 0.00,	TNODS= 0, STY= 0.00, THFTA=	THODS= 0, STY= 0.00,	TNODS= 0, STY= 0.00, THFTA=	TNODS= 0, STY= 0.00,	TNODS= 0, STY= 0.00,	TNGDS= 0, STY = 0.00, STY = 0.00, STY	TNODS= 5,	IFLXW=1,
35 10:07	0.0633 0.0485 0.0258	TWODE=3, IREV= 0, ID IPATCOP=0,	USELAGE   STX	0.0258 0.0485 0.0633 0.0710	0.0710	0.0000 TNODE=3, STX= 1.267,	INMODE:	-0.0743	-0.0578 -0.0485 -0.0377	-0.0258 -0.0131 0.0000	0.0258	0.0485	0.0653	THODE=3	ALF 0.0, INMODE 0, STX=1.388, S	INMODE= 0, STX=1.449, 8	INMODE 0, STX=1.509, 8	INMODE 0, STX=1.509, 8	IMMODE= 0, THODS= 0, TAPS= 0, T STX=1.509, STY= 0.00, STZ= 0.0000, ALF= 0.0 THFTA 0	INMODE 0, STX=1.509, 8	INMODE 0, STX=1.509,	IIMODE= 0, STX=1.509, S	INMODE 0,	IDWAK=1,
Jul 24 1995 10:07	1.207 1.207 1.207 1.207	&BPNODE &PATCH1	AFT &SECT1 1.2070	1.2070	1.2070	1.2070 &BPNODE &SECT1	0.0000	0.0131	0.0485 0.0578 0.0633	0.071 0.0743 0.0755	0.071	0.0578	0.0258	& BPNODE	4.SECT1	4SECT1	4.SECT1	&SECT1	&SECT1	&SECT1	&SECT1	&SECT1		4WAKE1

APPENDIX D. CANARD CRUCIFORM MISSILE DATA5 INPUT FILE

3 283							END	₽	EEND	GRAD	END	٩	T T	teno teno	Ω	CEND .		2	Q		ē		ê											
							3	E BND	3	27	ij	GNEAD	1	1 1	EEND	3	GNE	ERND	CEND	EEND	QN27		CEND											
							ď				IPATSYM=0,	0 P=0	YM=0,	9		PIMED,		, n= E	9	0 - 430	rH=1,	1.000												
							0.600	•			1, IPA	-: #	, IPATSYM=0	3, TNPS= 1, TINTS= 3, PATZ=0.0, PSCAL=1.0, PHEFE=-00.0 MODED=-0	HZZ=0.	,	0, PTHET=-90.0,NODEP ,PHY=0.0,PHZE=0.0	ILVAIS	9	, PHZZ-0.0	IPATSYM	SCALE=												
							SCALE.	NTS= 0,		TS= 3,	KAS8=	THET=9	1 = 3	75= 3, 7HE-T=-	0.0		HET-5	1	S= 3,	0.0	85* 1,		, o = s											
							ò	. E.	•	TINTE	7,	1.0, P.	, 2	MIT OF	O. PHY	:	1.0, P.1	:	TINIT	O, PHYY	3, KAS	0.000	TINTS=											
							0.000	RCOMP.			КСОНР	PSCAL=1.0, PTHET=9	XCOMB	PSCAL=	PHXX=1		PECAL=1.0, PHXX=1.0,P		3, TMPS= 1, TINTS= 3, PATZ=0.0, PSCAL=1.0, PTHETE.	HXX=1.	ксонр	=ZLS	•											
							TINTC=0 STZ=	0.0, TNPS= KE= 1. ?		TNPS		PATZ=0.0,	•	TNPS	; ·	•	000	•	TNPS	.0	•	00	THPS											
26	::::	:::	22:	<b>:</b>	22					'n	, MAKE						PATZ=0				HAKE-	0.0	•											
	0.0071							8		TWODE	IDPAT 1	PATY=0.0		TP TNODS= PATY=0.0,	PYY=0.0		99£	į.	TNODS- PATY-0.0,	PYY=0.0,	IDPAT- 1,	.0000, STY= 0.0000,	TNODS											
20826	0.20822	20822	20822	20822	20822	20822		, o . o .	IPATCOP=0, -TAIL TIP	<i>:</i>	COP-1, U	PATX=0.0, PA	0.00	LTYP= 1, PATX=0.0, P	, o	OP-1, DOWN	PATX=0.0, P PPXX=0.0, P IREV= 0, I	IPATCOP=0, T-DOWN-TAIL_TIP	0.0	ò		ě .	-	.0113	113	:::	113	113	611				611	
								ALF= 0 INMODE* IREV= 0	IPAT G-TAIL	ALL.	IREV IPAT	PATX	IPAT	ITYP:	PPXX	TAIL	PATX	-DOWN-	PATX=0	PPXX=0	IREV= 0, IPATCOP=0, -CANARD	STX-	IMMOD	99	77	7	17	77	77	, .		00		
9.0696	8.1667 8.2500	8.5000	8.5833	8.8333	0000	9.1667	SECTI	EPATCH1	HORE		EPATCHI VERI	EPATCH3		VERS EPATCH2 EPATCH3	FPATCH1	VERT	FPATCH3	VERT	CPATCH2		FPATCH1 HORE	68ECT1	.4825	0.3938	1275	0388	1.1388	3.2275 (	0.4050	4300	.4050	.3163 (	0.1388	2000

	QN25		GEND	QN23	FEND	G BND	CEND.	CRES	ERND ERND ERND			ON THE STATE OF TH	ONE S		GEND GEND	QNZY	GEND	QNET	EEND.	TEND	, 000.	EBND							
	LENRUN=0, LPLTYP=1,	LSTCPV=0,	RCORES=0.005			6658,	, , ,		NEWSID=0,	ASEME=0.00,	APZZ=0.00,	COMPZ= 0.0000,	NODEC= 0, CPZZ= 0.0000, CHZZ= 0.0000.	COMPZ# 0.0000,	CPZZ= 0.0000, CHZZ= 0.0000,	COMPE 0.0000, NODEC 0.0000	CHZZ 0.0000,	COMPZ= 0.0000, NODEC= 5, CPZZ= 0.0000, CHZZ= 1.0000	2,		0.0000, SCALE= 1	TINTE 0,							
,	LSTOUT=0, LSTFRQ=0,	INAB=0, LSTWA LRES=0.0005, TSTEP=0.3500,	PR=0.0, /SOUND=111 YAWDEG=0.	SMAX=0.0, PSI	WRY=0.0, WRE=0.0 DYMAX=0.0, DZMAX=0.0,		RMPY=0.00, RMPZ=0.00, NBCHGE=0, NCZONE=0,		NOCL=0, KSIDE=0, NEWNAB=0,		APYY=0.00, A		CTHET 0.00 CPYY 0.0000, CHYY 1.000,	0.000,	CPYY= 0.0000, CHYY= 1.000,	COMPY 0.2183, CTHET 0.0, CPYY 0.0000.	CHYY. 1.000,	COMPY= 0.2183, CTHET= 0.0, CPYY= 0.000, CHYY= 0.000,	1, MAKE= 0, KCOMP		0.0000, 8	1NOUS 0, INPS 0,	071	071	071	071	071	071	071
	LSTINP=2, LS	LSTGEO=0, L MAXIT=200, S NTSTPS= 3,	RCOREW=0.005, VINF=223.2, ALDEG= 10.00,	PHIMAX=0.0, TH	WRX=0.0, DXHAX=0.0,	WTX=0.0, WTY CBAR=0.4167, SR	NORSET-0,	NCZPCH=0, NORPCH=0, NORF=0,	NOCF=0, VNORM=0.0, KPAN=0, NBLIT=1,	ASEMM=0.00, ASCAL=1.00,	APXX=0.00, AHXX=0.00,	COMPX= 0.0000,	CHXX= 0.0000,	COMPX= 0.0000,	CHXX= 0.0000, CHXX= 0.0000,	COMPX= 1.2250, CSCAL= 1.000, CPXX= 0.0000.	CHXX= 0.0000,	COMPX= 1.2250, CSCAL= 1.000, CPXX= 0.0000, CHXX= 0.0000,	IREV- 0, IDPAT-	IPATCOI -TAIL	0000, HH,	0.20822 0.0		0.20822 -0.0071					
	&BINP2	CBINPS CBINPS	CBINP7	£BINP8A	6BINP6B	6 BINP 9	4BINP10	EBINP11	EBINP12 EBINP13	CASEM1	EASEH2	&COMP1	6 COMP2	&COMP1	6COMP2	£COMP1		4COMP1	LPATCH1	22	sect1	2500	0000	8.9167	7500	5833	5000	3333	2500

0.1050 0.0113 0.01014 0.01015 0.0111 0.1050 0.0101 0.01050 0.0101 0.01050 0.0101 0.01050 0.0000 0.000 0.0000 0.000 0.0000 0.000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.	QN27	6END 6END			tend fend fend fend	tend fend fend	tend fend fend fend fend	EEND EEND	Q 2 2 3 3
THECAO TH	TINTC=0 STZ= 0.0000, SCALE=	.0, TNPS= 8, TINTS= 0, E= 9, KCOMP= 3, KASS= 1,	-9, KCOMP= 3, KASS= 1,	NES 1, TINUS 3,  NES 0, ECCHP 4, RASS 1, IPATSYN-0,  EXEC. 0, PSCAL-1, 0, PTHET-80.0, NODEP-0  PRE-0.0, PHEXE-1, 0, PTHET-80.0, NODEP-0  PRE-0.0, PHEXE-0, PTHET-90.0, NODEP-0	TXE= 1, TINTS= 3, 0, NODEP-0 XXZ=0, PECK=1,0, PHYE-0,0, PHZE=0,0 AXE= -15, KCOMP= 4, KASS= 1, IPATSYM=0,	ATRE 1, TINE 3, ATE 0.0, PSCAL 10, PTHET 1-90.0, NODE 1-0 PZZ 0.0, PHXK-1.0, PHYT-0, C. PHZZ 0.0 AME 0, KCOMP 4, KASS 1, IPATSYH-0,	A7Z=0.0, PSCAL=1.0, PTHE7==90.0,NODEP=0 PZZ=0.0, HYNY-1.0,PHTATO.0,PZZ=0.0, AKE=1.0, RCOMF 4, KASS=1, ITATSTH=0, TNBS=1, ITATS=3, NODEP=0 AZZ=0.0, PSCAL=1.0, PHEZT=90.0,NODEP=0 PZZ=0.0, PHXK-1.0,PHEZT=0.0,NODEP=0 AZZ=0.0, PHXK-1.0,PHYY-0.0,HZZ=0.0	TNPS= 1, THNR=3,0,0,NODEP 0.0, PSCAL=1.0, FHRT=-90.0,PHRE=0.0 0.0, PHXX=1.0,PHXY=0.0,PHRE=0.0, 0, KCOMP= 1, KASS= 1, IPAKSYH=	SIX 0.0000, SCALE-0., THESE 0,
0.0113 0.	TNPC=0 STY= 0.4675	THETA. THODS= 3, IDPAT= 1, HA	TNODS=	TNODS= DPAT= 1, ATY=0.0, PYY=0.0,	TNODS- NTX-0.0, PYY-0.0, OPAT- 1,	THODS 3, PATY=0.0, PP PPYY=0.0, PP IDPAT= 1, HP	VERT-CANABLE DO PATY-0.0,	THODS. ATY-0.0, PYY-0.0, OPAT- 2,	

Page 4	!	Q Q Q	GNZ	gra9	QNST	e END	GEND	QN23	CEND	CEND	CEND	C END	<b>GEND</b>	QNE	FEND	enD	C END	GNEND	CEND	enD	e end	£ END	GN27	LEND	GRAD	EEND
		0.3488,	0.6163,	0.7682,	0.8966,	0.9741,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	1.000,	
		SCALE.	o, scale=	0, SCALE=	0, SCALE=	0, SCALE=	O, SCALE=	SCALE	. 0, SCALE=	. 0, SCALE=	. 0, SCALE	O, SCALE	. 0, SCALE=	. 0, SCALE=	O, SCALE	. 0, SCALE	= 0, SCALE=	= 0, SCALE=	= 0, SCALE=	SCALE=	SCALE	scale=	SCALE=	SCALE=	S= 0, SCALE=	, 0 = 8
<b>IISSILE</b>		0.0000.0	STIL 0.0000, STZ= 0.0000,	S= 0, TINTS= STZ= 0.0000,	TINTE 0.0000,	TINTS=	TINTS- 0.0000,	TINTS= 0.0000,	, TINTS=	TINTS.	TINTS-	0, TINTS= 2= 0.0000,	TINTS= 0.0000,	TINTS.	TINTS-0.0000,	TINTS.	S= 0, TINTS= STZ= 0.0000,	TINTE-	), TINTS=	TINTS- 0.0000,	, TINTS-	TINTS=	TINTS= 0.0000,	TINTS=	TINTS*	TINTS=
CANARD MISSILE			TNPS= 0, STZ= 0	INPS= 0, STZ= 0	0.0, TNPS= 0, 000, STE= 0	ENPS= 0,	TNPS= 0, STZ= 0	TNPS= 0, STZ= 0	THETA: 0.0, THODS: 0, THPS: 0, STY: 0.0000, STZ: 0.	THEIA 0.0, TNODS 0, TNPS 0, TINTS STY 0.0000, STE 0.0000,	TNPS= 0,	TNPS= 0,	PS.		TNPS= 0, STZ= 0.	TNPS= 0, STZ= 0.	TNPS= 0,	PS= 0, STZ=	STZ:	TNPS= 0,		TNPS * 0,	0.0, TNPS= 0, 000, STZ=	TNPS= 0,	, TNPS= 0, TIN , STZ= 0.0000,	0.0, ', TNPS= 0,
CAN	0.0	0.0000,	THOUSE 0, THPS= 0	THETA 0.0, TNODS 0, : STY 0.0000,	THETA 0.0, TNODS 0, SIY 0.0000,	S= 0,00,	THEIA= 0.0, TNODS= 0, T STY= 0.0000,	A= 0.0, S= 0, 0.0000,	THETA: 0.0, THODS: 0, TH STY: 0.0000,	S= 0, 0.0, 0.0, 0.0, 0.0	THETA 0.0, TNODS 0, TNPS 0, SIY 0.0000, SIZ=	THETA 0.0, TNODS 0, STY 0.0000,	THEIA= 0.0, TNODS= 0, Th STY= 0.0000,	THETA: 0.0, TNODS: 0, STY: 0.0000,	THETA 0.0, THODS 0, TNPS 0 GIY 0.0000, SIZ	THETA 0.0, TNODS 0, INPS 0 STY 0.0000, STZ=	THEIA= 0.0 TNODS= 0, STY= 0.0000,	THETA: 0.0, TN TNODS: 0, TN STY: 0.0000,	THETA	THETA: 0.0, THODS: 0, T STY: 0.0000,	THETA* 0.0, TNODS* 0, TNPS* 0 STY* 0.0000, STZ*	THETA: 0.0 TNODS: 0, STY: 0.0000,	THETA* 0.0, TNODS= 0, TN STY* 0.0000,	THETA: 0.0, TNODS: 0, TN STY: 0.0000,	THETA 0.0, TNODS= 0, STY= 0.0000,	TA= 0.0
	0.0	TNPC=1	THE TANDE	), THET) ), THODE 75, STY=	0, THETA= 0, TNODS= 78, STY= 0.	O, THET	O, THETO	O, THET	O, THET O, THOD	O, THET O, TNOD	0, THET 0, TNOD	O, THET	0, THETA= 0, INODS= 00, SIY= 0.	0.0, THET 0, TNOD 5000, STY	0, THET 0, THOU 300, STY-	.0, THE 0, TNOI 000, SIY	0, THE 0, INOI	0.0, THE		0.0, THE NE= 0, TWO 5.5000, STY	0, THE 0, TNO 000, STY	OOO, STY	0, THE 0, TNO 000, STY	0.0, THE 0, TNO 5000, STY	0, THE 0, TNO 1000, STY	.0, THE 4, TNO
5 15:19	0.2051	TNODE=3, SIX= 0.016	Ņ o	ALF= 0.0, INMODE= 0, STX= 0.1475,	ALF= 0.0, INMODE= 0, GTX= 0.2578,	ALF= 0.0, INMODE= 0, STX= 0.3700,	ALF 0.0, INMODE 0,	ALF= 0. INMODE= STX= 1.00	ALF 0. INMODE = 8TX 1.25	ALF 0. INMODE 5	ALF 0. INMODE 5	ALF 0.0, INMODE 0, STX 2.0000,	ALF- 0.0, INMODE= 0, STX= 2.2500,	ALF 0.0, INMODE 0, STX= 2.5000,	ALF= 0.0, INMODE= 0, STX= 3.0000,	ALF= 0.0, INMODE= 0, STX= 3.5000,	ALF 0 INMODE =	ALF= 0.0, INHODE= 0, STX= 4.5000.	ALF= 0.0, INMODE= 0, STX= 5.0000,	ALF= 0 INMODE= STX* 5.5	ALF= 0.0, INMODE= 0, STX= 6.0000,	ALF= 0.0, INMODE= 0, STX* 6.5000,	ALF= 0 INMODE= SIX= 7.0	ALF= 0.0, INMODE= 0, STX= 7.5000,	ALF= 0.0, T INMODE= 0, T STX= 0.0000, S	ALF= 0 INMODE=
Aug 16 1995 15:19	0.0361	EBECT1 6	ESECT1	FSECT1		L SECT1											LSECT	L SECT	£ SECT1	ESECTI	6 SECT1	£SECT1	4SECT1	4.SECT1	ESECT1	ď
	L																									
Page 3			QNE	CEND	QN9 7	GEND	gra9	CEND	CREAD	QN2 9	GNAT	Qual	CEND FEND	QN	FEND	GNET	GEND	Q CEND			QN					

CNA		GRAD	CEND		END	GNEND		2		CNS			CEND	EEND		CNE		CNE		į	2	END			<b>EEND</b>	ERND	
		900			1.000,				1.000,				1.000,				1.000,				1.000,				1.000,		
	•	1	,		SCALE=	٥,			SCALE.	۰,			SCALE=	۰,			SCALE	٠,			SCALE=	٠,			SCALE	,,	
TINTS		000	TINTS=		,0000,	TINTS=			,0000.	TINTS=			0.0000,	TINTS-			.0000.	TINTS=			,0000.	TINTS			.0000	TINIS	
TNP6= 0.		TINTC=0,	,		0 #2	TNPS= 0,		9	TZ= 0	PS= 0,			TINTC=0, 0, STZ= 0.0	TNPS= 0,		ė,	0 = 2	PS= 0,		ş	0 = 2	PS= 0,			2=	PS= 0,	
0.0°		TINTC	0.0,0		000	, , ,		0=14814	.0000	O, TWP			TINTC 0000			TINTC*0	,0000	O, TINP			0000, ST	O, TNP			TINTC=0,	0.0, TNP	
THETA-	2659	PC=0,	HETA	ପ୍ରସ୍ଥର	TNPC=0, STY= 0.	THETA-	0.0630 -0.1986 0.1202 -0.1702 0.1660 -0.1259	1 1 1 1 1	STY= 0.	TNODS=	1001	<b>0 ← -</b> 1	ETY = 0.	THETA	0.0630 -0.1986 0.1202 -0.1702 0.1660 -0.1259	1 TNPC=0,	STY* 0. THETA*	TNODS=	e ~ 0	1	STY= 0.	TNODS=	<b>6</b> 0 0	v i	INPC=0,	THETA:	, vo
0.0,	0.0071 -0.2082 0.0630 -0.1986 0.1202 -0.1702 0.1660 -0.1259	2 -0.069 08=3,	0.0	0.0071 -0.2082 0.0630 -0.1986 0.1202 -0.1702 0.1660 -0.1259	2 -0.007 DE-3, 0.0000,		0.178	2 -0.069	0.000,	DE= 4,	2 -0.170	3 -0.125 2 -0.069 2 -0.007	0.0000,	- AG	0.170	2 -0.007 0E=3,	0.000,	DE= 4,	2 -0.170	2 -0.069	0.000,	DE= 4,	2 -0.170	20.00	05-3, T	o - 6	0 -0.198
					O C 208	IN	0.120	3 0.196 3 0.208	STX	INMO	0.063	0.166	STX	INI	0.000	0.208	ALF-	1 0.007	0.120	0.208	STX=	INMO	0.063	0.196	DON'T SIC		
	8.4167 8.4167 8.4167 8.4167	8.416 8.416 4BPNO		8.5000 8.5000 8.5000	EBPNO		8.5833 8.5833	8.583	4.SECT	8.6667	8.666	8.6667 8.6667 8.6667	C SECT		8.7500 8.7500	8.7500 6.3500 6.3500	f SECT.	8.8333	8.8333 8.8333	8.833	ESECT.	8.9167	8.9167	8.9167	LSECT	9	9.0000

Page 5	CINE	Quanta de la companya	CEND		Quar	CEND	ERND		FEND	GNES		CEND	un a			e end	6 END		EEND	CEND.		QN
			IPATSYM=1,	1.000,		1.000,			1.000,			:	1.000,			1.000,			1.000,			1.000,
9	·		٦,	SCALE-	č	SCALE	°,		SCALE	٥,				;		SCALE	٠,		SCALE-	ò		SCALE.
MISSILE			1, KASS=	.0000	e Service Serv	,0000.	TINTS=		.0000.	TINTS			.0000,			,0000.	-SINIE		,0000,	TINTS=		0.0000,
CANARD	ç	,	, KCOMP=	0 =219	TNPS= 0,	0 # 2	TNPS= 0,		TINTC=0,	TNPS= 0,				ļ		22	TNPS= 0,		TINTC=0,	TNPS= 0,		TINTC=0,
CA	E CENTRAL CENT		HAKE- 0	,000	ò	00	, .		8	,		£4	, è	;		8	; ;		8	, , ,		ě
	881 775 644 645 644 644 644 645 645 645 645 64		IDPAT- 2,	STY 0.	TNODS=83 83 81 85 75	00 TNPC=0,	THETA		TNPC=0,	THETA	2226	71 TNPC=0,	THETA-	82 86 96	27.2	TNPC=0, STY= 0.	TNODS=	2222	ς. Ένειος,	THETA-	22222	TY= 0
5:19	-0.1981 -0.1685 -0.0644 0.0000 0.0000 0.1175 0.1175 0.1085		IREV= 0, IDPA IPATCOP=0,	0.0000,		0.00		0696 0.1009 -0.1009 0696 0.1206 -0.1699 0696 0.1665 -0.1252 0696 0.1967 -0.0686	0.000	- 20 - 20		2 -0.00 2 -0.00 0E=3,	, , ,	0.196	3 -0.12	0.0000,	DE= 4,	0.0630 -0.1986 0.1202 -0.1702 0.1660 -0.1259	2 -0.001 DE 3,	0.0,	1 -0.2082 0 -0.1986 2 -0.1702 0 -0.1259	977
5 1995 1	0 0.0644 0 0.1225 0 0.1081 0 0.1081 0 0.1081 0 0.1081 0 0.0644 0 0.0644	_	Ĕ	1	8.0 0.0 8.0 0.0644 8.0 0.1225 8.0 0.1685	0.2083 DE TNC 1 STX*	INMC	000000000000000000000000000000000000000	STXC	IN C	0.120	0.198	ALE				INNO	0.063	E TNO		00000	
Aug 16		₹ .	EPATCH1	6 SECT1	00000	B.0 EBPNOI		8 8 8 8 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	. 8 5		8.1317 8.1317 8.1317		22	9.1667	8.1667 8.1667 8.1667	ESECT1	8,2500	8.2500	6.2500 EBPNOD			EBPNOD ESECTI

QN25 EEND

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Page 8

CANARD MISSILE

END

ESECT1	8.2500 8.2500	8.2500 8.2500 8.2500	EBRODE ESECTI	8.3333	8	6.3333 6BPNODE 6SECT1	8.4167	8.4167	8.4167 8.4167 EBPNODE #SECT1	8.5000	8.5000	8 . 5000 EBPNOD	ESECT1	8.5833 8.5833	8.5833	8 : 583 10 E B P N O		8.6667 8.6667 8.6667	9.66	9.666 FBPNO		8.7500	8.750	8.750	EDES 5	8.833
	FEND	QNSS		PEND PEND	EEND		£ £ND	QNET		CEND CEND		CEND		Q.X.		GN25		QN23		Q Z		CIN 6	a de la companya de l	EEND		
	1.000,			1.000,			1.000,	,		YH=1,	1.000,				1.000,				1.000,				1.000,			
	SCALE 1			SCALE- 1	,		SCALE			1, IPATSYM=1,	SCALE-	•			SCALE=	٥,			SCALE.	٥,			SCALE=	٥,		
		TINTS 0,			TINTS= (			MTST			,0000,	TINTS=			,0000	TINIE			0.000.0	TINTS			,0000.	TINTS		
	rz= 0.0000,			Tz= 0.0000	,		0,0000	, •`		TC=0, 0, KCOMP= 1, KASS=	8TZ= 0.0	, o = s		•	TINTC=0,	TNPS= 0,		•	TZ=	TNPS= 0,			, TZ= 0	TNPS= 0,		
	TINTC=0,	o.u, TNPS=		TINTC=0,	0.0, TNP6=			₽.		INPC=0, TINTC=0 IDPAT= 2, MAKE= 0, K	,000	0.0, ', TNPS=			TINIC.	, 0.0, TNI			DOOO, S	,, o			TINIC=0	,		
	TNPC=0, STY= 0.00	NODS- 0,		PC=0,	HETA- NODS- 0,		PC=0,	HETA*	0.00 -0.2083 0.0030 -0.1986 0.1202 -0.1702 0.01203 -0.1703 0.01203 -0.1259	NPC=0, AT= 2, H	STY= 0.0	THETA- TNODS= 0		.1225 0.1685 .0644 0.1981 .0 0.2083	NPC=0, STY= 0.(	THETA-			STY= 0.	THETA= TNODS=	0.2082 0.0071 0.1963 0.0697 0.1660 0.1259		TNPC=0, STY= 0.	THETA	1000	<b>~</b> 9
0.0697	0.0071 3, 0000	0.0, T	-0.1702 -0.1259 -0.0697	-0.0071 -3, TR	0.0,	0.1702	100 00 10 10 10 10 10 10 10 10 10 10 10		-0.1986 -0.1986 -0.1702 -0.1259	o di Hori	)P=0, ruseiage 3.0000,		0.0644	0.1685 0.1981 0.2083	0.0000,	0.0	0.068	0.198	0.0000,	, 4°	0.000	0.198	TNODE=3, T	°.	0.0697	
- 1963	5.2082 -0.0071 TNODE=3, TI STX= 0.0000,	ALF INMODE 0.0071	0.1202	0.2082 TNODE	INHODE	0.0630	0.2082 TNODE	ALF INMODE	0.0 0.0630 -0.13 0.1202 -0.13 0.1660 -0.13	O.2083 TNODE	IPATC( ER AFT I STX= (	ALF.	. 2083 . 1981 . 1685	0.1225 0.0644 0.0	GONT	ALF INMOD	0.1967	0.0633	E TNOE	INMOL	0.1963 0.	0.0630	E TNOI		0.2082	0.120
	4.0000 4.0000 4.0000E	9.0833	9.0833	9.0833 EBPNODE		9.1667	9.1667 9.1667 \$BPNODE	f SECT1	9.2500	9.2500 EBPNODE	UPPER		000	8.0 0.1225 8.0 0.0644 8.0 0.0	SECT1	9090	8.0696	8.0696 8.0696 8.0696	LBPNODI		8.1317 8.1317 8.1317	8.1317	ESECT1		8.1667 8.1667 8.1667	8.1667

Pag	CNA			e e	in a		N N	į	Z 4		E E	3			ii ii	2			3	4		•	3	ن.			ug.	•	
	1.000,			1.000,				1.000,			1.000.				1.000.				1.000				1.000,				1.000,		
	ALE:			SCALE= 1				ALE-	ò		# H C C C		;		44.14.00	٥,			# # # CO				SCALE	•			SCALE=	<i>.</i>	
SILE	į	PERMIT			TINTS= 0,			;	#SEXIE			5			6	TINTS			9	TINTS			,0000	TINTS			,0000	-SINIL	
MIS	8.0			2= 0.000				Z= 0.00			TINTC=0,	12. C	;		TINIC=0,	TNPS= 0,			TINTC=0,	TNPS= 0,			TINTC=0, 30, STZ= 0.0000,	.o =s			TINTC=0, 00, STZ= 0.0000,	TNPS= 0,	
CANARD MISSILE	, ST2= 0,	TANES O		TINTC=0, 00, STZ= 0.0000,	.U. TNPS=		TRACEO	000, STZ= 0.0000,	INPS 0,		TINIC=0	0.0, STAT			TINIC=0	0.0, 0.0, TNPS			TINTC	0.0,			TINTC=	0.0, TNP			TINTC.	•	
ರ	TA- 0.0000	0 = 80		0.000	000 = 0,		Ş	Y= 0.000	,0 = 8do		, 0=0,	ALF 0.0000, STY 0.0000,	1		,0=0,	HETA 0.0000 HETA 0.0000 NODS 0.			PC=0,	TY= 0.00 HETA= NODS= 0,			TNPC=0,	THETA= TNODS= 0			TNODE=3, TNPC=0, T. STX= 0.0000, STX= 0.0000	THE LAT	
	000, SIY 0, IHE	4, TNO .0071 .0697	.1259 .1702 .1986	, ZOBZ , TNP (000, ST)	.0. 17K	0.1259	1.1986	0000, ST	4, TN 0.0071	0.1259	0.1986 0.2082 3, TNP	0000, 0.0, 11	0.0071	0.1259 0.1702 0.1986	0.2082 3, TW	0000	0.0071	0.1259 0.1702 0.1986	0.2082 -3, IN	0000 000	0.0071	0.1702	.0000.	0 4	0.0697	0.1986	1 0000 C	0.00, 0.0071 0.0697	
5 15:19	TX= 0.0	INMODE- 0.2082 0 0.1963 0	0.1660 0.1259 0.1202 0.1702 0.0630 0.1986	TNODE=3, TNPC=0, TINTC=0, TNODE=3, TNPC=0, TINTC=0, STX= 0.0000, STX= 0.0000, STZ=	ALF 0 INMODE 0.2082 0	1202	0.0630	STX= 0.0	INMODE= 4, TNODS= 0, 0.2082 0.0071	1.1262	1.0630 3.0071 TNODE=	STX= 0.	INMODE- 0.2082 0.1963	0.1660 0.1259 0.1202 0.1702 0.0630 0.1986	0.0071 TNODE	ALF=	0.2082	0.1660 0.1202 0.0630	0.0071 TNODE	SIX= 0.0000, SIX= 0.0000, ALF= 0.0, THEIA= 0.0, INMODE= 4, TNODS= 0, T	0.2082 0.0071 0.1963 0.0697 0.1660 0.1259	0.1202	TNODE = 3	ALF 0.0, THETA 0.0, INHODE 4, TNODS 0, TNPS 0,	0.1963	0.1202	CONT.		
Aug 16 1985 15:19	ESECT1 8	2500 0.	8.2500 0.8.2500 0.8.2500 0.000			8.3333 O 8.3333 O 8.3333 O	3333	BPNODE SECT1	.4167 0	4167	8.4167 8.4167 EBPNODE		5000	8.5000	B.5000	ESECT1	8.5833	8.5833 8.5833	6.5833	s SECT1	8.6667 8.6667 8.6667	8.6667	C BPNODE		8.7500 8.7500 8.7500	8.7500	8.7500 EBPNODE ESECTI	8.8333	8.8333
¥.	S3			<u> </u>				<b>4</b>																					
7																											۵		و
Page 7		<b>GEND</b>	QNS		CEND	CNI			GRAD	GNES			CHANGE SERVICE		GEND			Q CAN	e end		QN25				CNA		CRAS		CEND
		,000			6				,000,				:H=1,	1.000,				1.000,				1.000,				1.000,			
		ALE- 1.			-				CALE- 1				, IPATS	CALE				SCALE=	š			CALE=	o`			SCALE=	ò		
SILE		), 8C	INTS= 0,		ì	INTS= 0,			ě,	CINTS- 0			KASS= 1	9 ,00	TINTS= (			,00	TINT6=			,000	TINTS			,000	TINTS		
SIM		0.000	, ,			, o			Z= 0.000	,			OMP= 1,	00.0 =2:				rz= 0.00	· •			rz= 0.00	, ,			, ;rz= 0.0	, ,		,
CANARD MISSILE		INTC=0,	TNPS=		INTC=0,	o, or			INTC=0,	O, TNPS=			FINTC=0,	6,	.0, TNPS=			TINTC=0,	.0, TNPS			TINTC=0 00, 8	TNPS			HINHC=0	TNPS		TINIC+0
3		0,0000,0			0	. 0 . 000 S= 0,			0,000	EA. 0.			2, HAK	000.0	TA= 0, DS= 0,			000.00	77A= 0, 3DS= 0,			KEN 0.000	0 = 500			C=0, Y= 0.00	0008= 0,		,0=0,
	697	071 TNPC=( 0, STY=	, THET	205 259 259	1697 1071 TNPC=	O, SIY-	1986	1259	10071 TNPC	THE	2083 1986 1702	1259 0697	TNPC IDPAT=	IAGE 00, STY	AND TARE	0000	1685	ZOB3 TNPC 300, STY	AH N	.0056 .0686 .1252	.1699 .1984 .2083	OOO, STI	.007	.1259	.1986	OOO, ST	4, TW	0.1259 0.1702 0.1986	1.2082 1, TNP
15-19	63 -0.0	100E=3,	ALF= 0.0, THETA= 0.0, TNPS= 0, TINES= 0, EEND 5.0813 0.0071-0.0071-0.0070	630 -0.1 202 -0.1 560 -0.1	963 -0.0 082 -0.0 NODE=3,	X= 0.00( F= 0.0	630 -0.	202	NODE 3,	F 0	202 -0-	1963 -0.	TNODE=3,	PATCOP=0 NFT FUSE IX= 0.00	LF 0.	833	<b>2</b> 25	TNODE=3, TX= 0.00	NMODE -	2083 0. 1967 0.	1206 0633 0056 0	TNODE=3	10MODE=	1963 0	0630	TNODE=3	INMODE -	8.1667 0.1963 0.069/ 8.1667 0.1560 0.1259 8.1667 0.1202 0.1702	.0071 TNODE=3
Aug 46 1005 15:1	0.19	00 0.20 00 0.20 00 TN	ALE INF	33 0.00	33 0.1 33 0.2 006 13	TA AL	67 0.0	1.00	100E	: 22 :	500 0.0 500 0.0 500 0.1	500 0.1	NODE 1	II UPPER A	28	0.70	0.12	NODE CT1 S	2 =	696 0.	696 0.	NODE	I 1317 0.	1317 0.	1317 0.	PNODE ECT1 5	1667 0.	11667 0.	1667 U
		S BPNC	9.08	888	80 6 80 6	1820	9.16	9.16	6 11 6 1 6 1 6 1 6 1 6 1 6 1 6 1 6 1 6	ú 6	9 9 9	66	9.2 6.87	325		999		8 . 0 F B P		000	8 8 8	£81	6	000		E 3	89		

									EEND	ERND		CEND	Q N	GNS	CND	ERND	t END	ERND	CEND	EEND	CKND	END	CEND	EEND	END	CEND	(2) h		C C C	CNS	
									1.000.		5= 1.000,	,008.0 =2	. 0.600,	. 0.400,	. 0.200,	. 0.000,		INTRW= 1,	KWPAN1=0,	INTRW- 1,	KWPAN1=0,	INTRW= 1,	KWPAN1=0,	INTRW= 1,	KWPAN1=0,	INTRH- 1,	KWPAN1=7,	KWPAN1=0,	KWPAN1=0,	INTRW- 1,	
									TINIC=3, STZ= 0.0000. SCALE=	D. TINTS	STZ= 0.0000, SCALE=	TNPS 0, TINTS 0, STZ 0.0000, SCALE	TNPS= 0, TINTS= 0, STZ= 0.0000, SCALE=	TNPS= 0, TINTS= 0, STZ= 0.0000, SCALE=	TNPS= 0, TINTS= 0, STZ= 0.0000, SCALE=	.0, TNPS= 0, TINTS= 0, STZ= 0.0000, SCALE=	TNPS= 0, TINTS= 0,	ITRFTZ= 1,	KWLINE=0, INITIAL=0,	ITRFIZ= 1,	KWLINE=0, INITIAL=0,	ITRFTZ= 1,	KWLINE-0, INITIAL-0,	ITRFTZ= 1,	KWLINE-0, INITIAL-0,	ITRFTZ= 1,	KWLINE=5,	KWLINE=1,	KWLINE=5, INITIAL=0,	ITRFIZ= 1,	
0.2083 0.0 0.2051 0.0 0.1957 0.0	000	000	0.0		0	000	0.0	000	NPC=10, STY= 0.00.	THETA 0.	STY= 0.00,	TNODS 0, STY = 0.00,	THEIA 0.0, TNODS 0, TY 0.00,	THETA 0.0, TNODS 0, STY 0.00,		• •		IFLXW=1,	KWSIDE=2, NODEW=3,	IFLXW=1,	KWSIDE=2, NODEW=3,	IFLXW=1,	KWSIDE=2, NODEW=3,	IFLXW=1,	KWSIDE=4, NODEW=3,	IFLXW=1,		KWSIDE=2,	KWSIDE=2, NODEW=3,	IFLXW=1,	
111	11	117	•		-				FE	Z	STX= 9.4167	INMODE 0,	INMODE 0, STX=9.4167,	0.0,			ů	IDWAK=1,	KWPACH=1, KWPAN2=0,	IDWAK=1,	KWPACH=2, KWPAN2=0,	IDWAK-1,	KWPACH=9, KWPAN2=0,	IDWAK-1,	KWPACH=10, KWPAN2=0,	CHAKE! IDWAK=1,	KWPACH=21,	KWPACH-25,	KWPACH=27, KWPACH=3,	IDWAK-1,	-Y-BODY-VORTEX-WAKE
0.0000	0.1339	0.1804	0.2051	0.2051	0.1804	0.1596	0.1042	0.0361	EBPNODE ESECT1		ESECT1	£ SECT1	4 SECT1	ssect1	ESECTI	£ SECT1		CWAKE!	CWAKE2	EWAKE1	TAILS EWAKE2	CHAKE1 1	EWAKE2	EWAKE1	6WAKE2	6WAKE1	EWAKE2	6WAKE2	EWAKE2	EWAKE1	-X-BO

300																			•
Page 9	#END	QNAT	QNZT	Quar	Q Nay	GEND	····	GEND	GNAS		FRND	QNZT			FEND	EEND		QN P3	
CANARD MISSILE	= 0.0000, SCALE= 1.000,	0, TINTS= 0,	= 0.0000, SCALE= 1.000,	0, _ TINTS= 0,	= 0.0000, SCALE= 1.000,	0, TINTS= 0,		- 0.0000, SCALE- 1.000,	O, TINTS* O,		* 0.0000, SCALE* 1.000,	), TINTS= 0,			(P= 1, Kass= 1, Ipatsym=1,	.0000, SCALE= 1.000, 0, TINTS= 0,			0.0000, SCALE= 1.000,
שושט	1702 1986 1082 17PC=0, TINTC=0, 10, ETY= 0.0000, STE=	TNPS	702 1986 1082 THPC=0, TINTC=0, 10, SIY= 0.0000, STZ=	), THEEA 0.0, 1 THODS 0, THPS 001 1071 1259	1986 1082 TWPC=0, TINTC=0, TWPC=0, STZ=0, GTZ=0,	1, TNODS= 0, TNPS= 0	702 202 202 202 202	TNPC=0, TINTC=0, 10, STY= 0.0000, STZ=	NODS= 0, TNPS=	259 702 986	TNPC=0, TINTC=0, 0,0000, ST2=	TNODS 3, TNPS 0		TIMIC.	IDPAT= 2, MAKE= 0, KCOMP=	STY= 0.00, STZ= 0 THETA= 0.0, TNODS= 0, TNPS=	1,1086 1,1702 1,1702 1,0559 1,0000 1,0597	0=0	333, STY= 0.00, STZ= 0.00, THETA= 0.0, THETA= 0.0
Aug 16 1995 15:19	6.833 0.1202 0.1702 6.833 0.0630 0.1986 6.833 0.0071 0.2082 6.BPNODE THOCE=3, THPC=0, 6.SECTI 6TX= 0.0000, ETX= 0.	ALF= 0.0 INHODE= 4 8.9167 0.2082 0.0 8.9167 0.1969 0.1	8.9167 0.1202 0.1 8.9167 0.0630 0.1 8.9167 0.0071 0.2 EBENODE TNODE=3, ESECT1 STX= 0.000	ALTHORE 0.0, THETAE 0 9.0000 0.2082 0.0071 9.0000 0.1963 0.0687 9.0000 0.1660 0.1259 9.0000 0.1202 0.1702	9.0000 0.0630 0.1 9.0000 0.0071 0.2 6BPNODE TNODE=3, 6SECT1 8.7X 0.000	INHODE = 1	9.0833 0.1865 0.1 9.0833 0.1860 0.1 9.0833 0.0820 0.1 9.0833 0.0630 0.1	BPNODE SECT1	}	9.1667 0.1963 0.0 9.1667 0.1963 0.0 9.1667 0.1262 0.1 9.1667 0.030 0.1	PRODE SECTI	INMODE 0.2083	9.2500 0.1660 0.1 9.2500 0.1202 0.1 9.2500 0.0630 0.1	THODE	IREV= 0, IPATCOP=0, FUSELAGE	STX= 0.0 ALF= 0 INMODE=	0000000	.2500 0.1202 0 .2500 0.0630 0 .2500 0.0 0	SECTI STX= 9.3

·····								
	KWPAN2	=0,	NODEW=0,		INITIA			& END
EWAKE2	KWPACH:		KWSIDE		KWLINE		KWPAN1=0,	SEND
	KWPAN2	<b>=</b> 3,	NODEW=	5,	INITIA	L=0,		<b>T</b> DIND
<b>L</b> ONSTRM	NONSL :	=0, KPSL	= 20,5	& END				
EBLPARAM RN =2000000,		VISC	&END					
		0,	MIZOT C-	. 0				SEND
£VS1 £VS2	X0= MAOTK≃	3.00000,		2.0000,	20=	-2.0000.	INTVSR= 1,	& END
	X1=			2.0000,			NPT1= 16,	& END
	X2=	3.0000,	Y2=	16.000,			NPT2= 3,	<b>EEND</b>
avs. avs5	X2- X3=	3.0000,	¥3=	2.0000,			NPT3= 18,	&END
		-						
€VS6	XR0=	0.0000,		0.0000,			INTVSC= 1,	SEND
EVS7	XR1=			10.0000,				
	XR2=	0.0000,	YR2=	0.0000,		1.0000,		SEND
£VS8	R1=	0.5000,		5.0000,			PHI2=330.0,	&END
EVS9	NRAD=	10,	NPHI=	12,	nlen=	5,		& END
eslin1	NSTLIN:	=0						& END
ESLIN2	SX0=	2.0000,	SYOR	5.0000,	SZ0=	-0.5000,		
#9TTW5	SU≃	0.0000.		15.0000,			INTSL= 1,	<b>EEND</b>
SLIN2	SX0=	2.0000,		5.0000,		-0.4000,		
BOTTINE	SU=	0.0000		15.0000,			INTSL= 1,	SEND
SLIN2	SX0=	2.0000,		5.0000,		-0.3000,		
ROLLINZ	SU=	0.0000,	SD=	15.0000,			INTSL= 1,	SEND
SLIN2	SX0=	2.0000,		5.0000,		-0.2000,	•	
EGHTNY	SU=	0.0000,		15.0000,			INTSL= 1,	& END
SLIN2	SX0=	2.0000,	SY0=	5.0000,		-0.1000,		
*******	SU=	0.0000.		15.0000,		0.1000,	INTSL= 1,	& END

APPENDIX E. TANGENT-OGIVE NOSE BODY DATA5 INPUT FILE

ETCOM Mayor (Blunt Tail Body & Fuselage LESTOUT-0, LSTRAD-0, LENTUN-0, LESTOUT-0,  LESTOUT-0, LSTRAN-0, LENTUN-0, LESTOUT-0,  LESTOUT-0, RETS-0, RCORES-0.005  VEGUND-1116, DELAK-0, THEDOT-0.0, THEDOT-0.0,  VERTS-0, NETS-0,		CRET	CNSS	6 END	CNST	QN25	QN27			CEND	CEND	QN23 S CN23 S CN	QN27	CNA		QN29	1,		C END										CNAS		TEND	•	2, <b>LEND</b>	
### ### ### #### #### ################	4	RUN=0, IPLITYP=1,	STCPV=0,	CORES=0.005		THE DOT-0			18,			NEWELD=0,	ME-0.00,	10.00	OMPS= 0.0000,	PEE 0.0000,	KA58= 1	, SCALE												SCALE-	TS= 0,	BCALLE .	SCALE-	4 - C
1510   1511   1510   1511   1510   1511   1510   1511	(Blunt Tail	, LSTFRQ=0,	WX. = 0,	-S.0,	D=1116.0,	G=0.0, PHIDOT=0.0	0.0, PSIMAX=0.0,	.0, DZHAX=0.0,	.0179, GSPAN=0.30	0.00, RMPE=0.00, =0. NCZONE=0.	0.0, VREF=0.0,				,	1.000,	MAKE- 0,	878	0.0, 0, TNP6= 0										PTNTC=3	.0000, STE- 0.0	THPS- 0,	21.0	MP6= 0,	, -anne
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Aug 1199513:53	9			DATAS			Page 3
ALF" O INHODE SECTI SIX 0.8	500	THETA 0.0, T THODS 0, T STY 0.0000,	0.0,	0.0, , TMPs= 0, TINTS= 0000, STR= 0.0000,	0, SCALE= 1.	1.000,	0435
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INMOI STX-	0.0.6	THETA 0.0, TNODS 0, STY 0.0000,	, , , ,	TNPS= 0, TINTS= 6TS= 0.0000,	O, SCALE-	1.000,	GN29
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ALF 0. INHODE 1.02	323	THETA: 0.0 THODS: 0, ETY: 0.0000,		TNPS 0, TINTS STZ 0.0000,	O, SCALE-	1.000,	QNZT
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ALE CTI STX 1.10	900	TNODS		TWP8* 0, TINTS* STE= 0.0000,	. N. L. S.	1.000,	END
ALL O INHODE - CERCTI STX 1.1	902	TWODS-		THEIA. 0.0, TMPS. 0, TINTS. 0, STY. 0.0000, STE. 0.0000, STE. 0.0000, ST	NIS-	1.000,	ERND
INDESTI STX 1.20	: : :	TNODS 0,		TMP6- 0, TINTS- 8TE- 0.0000, 80	= 0, SCALE= 1.000,	. ,00	ERND
ALE 0.0, INMODE 0, ESECTI STX 1.260,		INODS.		0.0, TNP8= 0, TINTS= 0, STE= 0.0000, SCALE=	0, MLE= 1.00,		QNST
ALF= INHODE= ESECT1 STX= 1.		THETA.		), THETA. 0.0, ), TNODS. 0, TNPS. 0, TINTS. ), STX. 0.00, STZ. 0.0000, SCJ	SCALE 1.00,		CNST
ALF 0.0 INHODE 0 ESECT1 STX=1.388,	9.0, 388, 83	THETA: TNODE:	, ,	TMPS= 0, TINTS= 0, TE= 0.0000, SCALE=	0, 12* 1.000,		GNE
ALF 0.0, INHODE 0, ESECTI STX-1.449, 87		THETA THODS		TNP8= 0, TINTS= 0, 8TE= 0.0000, SCALE=	0, 1.00,		GNS
ALK= INMODE ESECTI STX=1.	ALF 0.0, INHODE 0, STX-1.509, 81	THETA	•	'TNPS= 0, TINTS= 0, STE= 0.0000, SCALE=	0, LE* 1.000,		QNZT
ALF 0.0, INHODE 0, ESECT1 STX=1.509, 61	0 80 c	THEIA 0	• •	'TNP8= 0, TINTS= 0, STE= 0.0000, SCALE=	0, 1,E= 0.800		GN23
INMODE ESECTI STX=1.	INMODE 0, SIX=1.509, 87	TNODS 0, SIY 0.00,	•	TNP8- 0, TINIS- 0, SIE- 0.0000, SCALE-	0, LE= 0.600,		QN23
INWODE ESECT1 STX=1.	INHODE 0, STX=1.509, 81	TWODE		THPS= 0, TINTS= 0, STE= 0.0000, SCALE=	.0, LB= 0.400		ERND
ALF 0.0 INHODE 0.0 48ECT1 STX=1.509,		TNODS		TNPS= 0, TINTS= 0, STI= 0.0000, BCALE=	0, LE 0.200		QN23
ALF= INHODE \$68CT1 STX=1.	ALF 0.0, INHODE 0, STX=1.509, 87	THETA. TNODS 0, STY 0.00,		0,000	HE 0, BCALE 0.000,		GNA
INHODE		TNODS	, ,	TNPS 0, TINTS	•		QN27
GWAKEL IDWAK-1, +Y_FUSELAGE WAKE	1,		IFLXW=1,	ITRFIE= 1,	INTRW= 0,	٠,	QNE
CHAKE2 KWPACH=1, KWPAN2=44	ij	NOD	KWGIDE=2, Nodew=3,	KWLINS-19, Initial-0,	KWPAN 1 = 1 9	1=19,	CEND
ENAKE1 IDWAK=1, -Y PUSELAGE WAKE	1,	E	IFIJON-1,	ITRFIZ- 1,	INTRM- 0	•	END
EWAKE2 KWPACH=2, KWPAN2=44,	ij	KWS	KWSIDE=2, NODEW=5,	KWLINE-11, INITIAL-0,	KWPAN	Kwpani=19,	CRND
CONSTRM NONSL =0,		KPSL = 2	- 20,50,80,	,			ERND
GBLPARAN RN =20	-2000000,	Z	VISC = 0.	= 0.00016, NSLBL = 1,2,3,	2,3,		QN23
4V61 NVOLR= 0,	,	NVO	NVOLC= 0,				6.END

## APPENDIX F. SAMPLE PARAM.DAT FILE

	Jun 6 1995 09:19 PARAM.DAT Page	
		<u> </u>
	PARAMETER (NSPDIM = 10000)	
	The state of the s	
0000	(ALSO NUMBER OF SECTIONS ALLOWED PER PATCH) (ALSO NUMBER OF ROWS OR COLUMNS + 1 ALLOWED ON A PATCH) CAUTION: DO NOT SET THIS PARAMETER TO LESS THAN 50!	İ
	PARAMETER (NBPDIM = 500)	
	NUMBER OF WAKE PANELS ALLOWED	i
	PARAMETER (NWPDIM = 4900)	
0	NUMBER OF WAKE COLUMNS OR ROWS ALLOWED ON EACH WAKE	
٥	PARAMETER (NWCDIM = 1000)	
d	NUMBER OF WAKES ALLOWED	
c	PARAMETER (NWDIM = 50)	
0	NUMBER OF SCAN VOLUMES OF EACH TYPE ALLOWED	ı
	PARAMETER (NSVDIM = 19)	
0	NUMBER OF POINTS PER OFF-BODY STREAMLINE ALLOWED	i
٥	PARAMETER (NSLPDIM = 2000)	
0 0	NUMBER OF POINTS PER ON-BODY STREAMLINE ALLOWED	
c	PARAMETER (NONSLPDIM = 2000)	
d	NUMBER OF GROUPS OF PANELS ON WHICH NONZERO NORMAL VELOCITY IS PRESCRIBED	
C	PARAMETER (NVELDIM = 20)	
d	NUMBER OF WAKE CORNER POINTS ALLOWED	١
c	PARAMETER (NWCPDIM=(NWPDIM + 1) *2)	1
d	NUMBER OF SURFACE CORNER POINTS ALLOWED	
c	PARAMETER (NSCPDIM=(NSPDIM + 1)*2)	1
ā	NUMBER OF EDGE PANELS ALLOWED ON A PATCH	1
С	PARAMETER (NEPDIM = NBPDIM * 4)	
00000	PARAMETER CONTROLLING WHETHER THE DOUBLET INFL. COEFF. MATRIX IS STORED ON DISK OR IN RAM. IF INRAM IS SET TO 1, MATRIX IS STORED ON DISK.  IF INRAM IS SET TO NSPDIM, MATRIX IS STORED IN RAM. NOTE THESE ARE THE ONLY TWO CHOICES!!!! IF ANY OTHER VALUE IS ENTERED, THE CODE WILL FAIL!!!	
	PARAMETER (INRAM = 1)	

## APPENDIX G. SAMPLE COMMON.F FILE

```
COMMON.F
 Feb 28 1995 08:32
                                                                                                                                                      Page 1
            COMMON/ BLDATA
                                                  FSVEL, RII, BLS (NONSLPDIM)
                                                  BLCP(NONSLPDIM), BLX(NONSLPDIM), BLY(NONSLPDIM), BLZ(NONSLPDIM), BLU(NONSLPDIM),
                                                  VISC, DSTAR (NONSLPDIM), BLTHETA (NONSLPDIM), RH (NONSLPDIM),
                                                  CF (NONSLPDIM),
DUDN (NONSLPDIM), DEL (NONSLPDIM)
            COMMON/ BLDATAI
COMMON/ CONST
                                                  NBLIT, NSLPTS, LAMSEP, ITRAN, ITRBSEP
                                                 PI, EPS, FOURPI, CBAR, SSPAN, SREF, RMPX, RMPY,
                                                  SOLRES, RCORS, RFF, RCORW
            COMMON/ CONSTI / COMMON/ INTERNAL /
                                                  MAXIT
                                                  CZDUB, VREF
            COMMON/ INTERNALI/
COMMON/ TSTEP /
                                                  NCZONE, NCZPCH
                                                 NTSTPS, ITSTEP
KPAN (NSPDIM), KSIDE (NSPDIM), NEWNAB (NSPDIM),
            COMMON/ NEWNAB
                                                  NEWSID (NSPDIM), NBCHGE
                                                  NABOR (4, NSPDIM), NABSID (4, NSPDIM)
NPAN, NPATCH, NWPAN, NWAKE, NCOMP, NASSEM
             COMMON/ PNABOR
             COMMON/ NUM
            COMMON/ ONSET
                                                  ALPHA, ALDEG, YAW, YAWDEG, WIND(3,3), VINF, VSOUND
                                                 WINDIS,3,YNF,VSOUND
SYM, GPR
PNAME(6,NPDIM)
IDENT(NPDIM), IPAN(NPDIM), KLASS(NPDIM),
KOMP(NPDIM), LPAN(NPDIM), NCOL(NPDIM),
NPANS(NPDIM), NROW(NPDIM)
            COMMON/ SYMMETRY /
COMMON/ PATNAM /
COMMON/ PATCHES /
                                                 NPAMS (NPDIM), NROW (NPDIM)
LSTINP, LSTOUT, LSTGEO, LSTNAB, LSTWAK,
LSTFRQ, LSTCPV, LSTHLD, LPLTYP
NOCF (NVELDIM), NOCL (NVELDIM), NORF (NVELDIM),
NORL (NVELDIM), NORPCH (NVELDIM), NORSET
VNORM (NVELDIM)
            COMMON/ PRINT
            COMMON/ VELSETI
            COMMON/ VELSET
            COMMON/ RUNCHTRL /
COMMON/ SOLUTION /
                                                  LENRUN
                                                 LENRUN
SIG(NSPDIM), DUB(NSPDIM), PDUB(NSPDIM),
WDUB(NWPDIM), VX(NSPDIM), VY(NSPDIM),
VZ(NSPDIM), VXR(NNPDIM), VYR(NNPDIM),
VZR(NNPDIM), DIAG(NSPDIM),
RHSV(NSPDIM), VNORMAL(NSPDIM), CPDUB(NSCPDIM),
VCPX(NSCPDIM), VCPY(NSCPDIM), VCPX(NSCPDIM),
CPPDUB(NSCPDIM), VC(NSCPDIM), VCPX(NSCPDIM),
VC(NSCPDIM), VC(NSCPDIM), VC(NSCPDIM)
                                                 XC(NSPDIM), YC(NSPDIM), ZC(NSPDIM),
PCS(3,3,NSPDIM), AREA(NSPDIM), PFF(NSPDIM),
CPSX(NSCPDIM), CPSY(NSCPDIM), CPSZ(NSCPDIM),
            COMMON/ SPANEL
                                                  SMP (NSPDIM), SMQ (NSPDIM)
                                                 ICPS (NPDIM), KPTYP (NSPDIM)
JPLOT, JDUBIC,
JSORIC, IMU, JSL
            COMMON/ SPANELI
            COMMON/ SCRFILES
                                                  INTW (NWDIM)
            COMMON/ INTRSCT
                                                 OMEGA(3), VFR(3), DTSTEP,
PHIDOT, THEDOT, PSIDOT,
PHIMAX, THEMAX, PSIMAX, WRX, WRY, WRZ,
            COMMON/ UNSTDY
                                                 DXMAX, DYMAX, DZMAX, WTX, WTY, WTZ
WNAME(6, NWDIM)
            COMMON/ WAKNAM
                                                 NWCOL(INDIM), NWROW(NWDIM), IWPAN(NWDIM),
LWPAN(NWDIM), IDENTW(NWDIM),
KWPU(NWCDIM,NWDIM), KWPL(NWCDIM,NWDIM),
            COMMON: WAKESI
                                                 IFLEXW(NWDIM), ITREZ(NWDIM)
PHIU(NWCDIM,NWDIM), PHIL(NWCDIM,NWDIM), XCW(NWPDIM), YCW(NWPDIM), ZCW(NWPDIM),
            COMMON/ WAKES
            COMMON/ WPANEL
                                                  PCSW(3,3,NWPDIM), AREAW(NWPDIM),
                                                  PFFW(NWPDIM)
                                                 CPWX(NWCPDIM), CPWY(NWCPDIM), CPWZ(NWCPDIM) ICPW(NWDIM)
           COMMON/ WPANELI
COMMON/ MDUBIC
COMMON/ ONSTRML
                                                 DUBICWW (INRAM, NSPDIM)
                                                 NONSI.
     TYPE DECLARATIONS
            LOGICAL SYM, GPR, FAR, CLOSED
CHARACTER*4 PNAME, WHAME, TITL
INTEGER THODS, THPS, THITS, THODE, THPC, THITC
            INTEGER UPNABOR, UPNABSID, DNNABOR, DNNABSID
С
```

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